2008
CITY OF HOUSTON
COMMERCIAL ENERGY CONSERVATION CODE

Based on
ANSI/ASHRAE/IESNA Standard 90.1-2004
(Includes ANSI/ASHRAE/IESNA Addenda listed in Appendix F)

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Legend for Marginal Markings

- Language was added or modified by the City of Houston, from the original ASHRAE 90.1 – 2004 document.

- Language was deleted or modified by the City of Houston, from the original ASHRAE 90.1 – 2004 document.

Special Thanks

To all the Construction Industry Council members who worked diligently on this project. Your contribution of time and expertise are appreciated.

1. PURPOSE

The purpose of this code is to provide minimum requirements for the energy-efficient design of buildings except low-rise residential buildings.

These regulations shall be known as the *City of Houston Commercial Energy Conservation Code*, may be cited as such, and will be referred to herein as "this code." *The City of Houston Construction Code* collectively includes this volume and certain other codes, pamphlets, specifications, and documents that are adopted in or by reference to the Adopting Ordinance, City of Houston Ord. No. 2002-399.

2. SCOPE

2.1 This code provides:

(a) minimum energy-efficient requirements for the design and construction of:

1. new buildings and their systems,
2. new portions of buildings and their systems, and
3. new systems and equipment in existing buildings and

(b) criteria for determining compliance with these requirements.

2.2 The provisions of this code apply to:

(a) the envelope of buildings provided that the enclosed spaces are:

1. heated by a heating system whose output capacity is greater than or equal to 3.4 Btu/h·ft^2 or
2. cooled by a cooling system whose sensible output capacity is greater than or equal to 5 Btu/h·ft^2, and

(b) the following systems and equipment used in conjunction with buildings:

1. heating, ventilating, and air conditioning,
2. service water heating,
3. electric power distribution and metering provisions,
4. electric motors and belt drives, and
5. lighting.

2.3 The provisions of this code do not apply to:

(a) single-family houses, multi-family structures of three stories or fewer above grade, manufactured houses (mobile homes) and manufactured houses (modular),

(b) buildings that do not use either electricity or fossil fuel, or

(c) equipment and portions of building systems that use energy primarily to provide for industrial, manufacturing, or commercial processes.

2.4 Where specifically noted in this code, certain other buildings or elements of buildings shall be exempt.

2.5 This code shall not be used to circumvent any safety, health, or environmental requirements.

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3. DEFINITIONS, ABBREVIATIONS, AND ACRONYMS

3.1 General. Certain terms, abbreviations, and acronyms are defined in this section for the purposes of this code. These definitions are applicable to all sections of this code. Terms that are not defined shall have their ordinarily accepted meanings within the context in which they are used. Ordinarily accepted meanings shall be based upon American standard English language usage as documented in an unabridged dictionary accepted by the *adopting authority*. Terms that are not defined in this code but are defined in other volumes of the *City of Houston Construction Code* shall have the meanings ascribed to them in those codes.

3.2 Definitions

above-grade wall: see *wall*.

access hatch**:** see *door*.

addition**:** an extension or increase in floor area or height of a building outside of the existing building envelope.

adopting authority**:** the agency or agent that adopts this code.

alteration**:** a replacement or addition to a building or its systems and equipment; routine maintenance, repair, and service or a change in the building's use classification or category shall not constitute an alteration.

annual fuel utilization efficiency (AFUE)**:** an efficiency descriptor of the ratio of annual output energy to annual input energy as developed in accordance with the requirements of U.S. Department of Energy (DOE) 10CFR Part 430.

attic and other roofs: see roof.

authority having jurisdiction**:** the agency or agent responsible for enforcing this code.

automatic**:** self-acting, operating by its own mechanism when actuated by some non-manual influence, such as a change in current strength, pressure, temperature, or mechanical configuration. (See *manual*.)

automatic control device**:** a device capable of automatically turning loads off and on without manual intervention.

balancing, air system**:** adjusting air flow rates through air distribution system devices, such as fans and diffusers, by manually adjusting the position of dampers, splitter vanes, extractors, etc., or by using automatic control devices, such as constant air volume or variable air volume boxes.

balancing, hydronic system**:** adjusting water flow rates through hydronic distribution system devices, such as pumps and coils, by manually adjusting the position valves, or by using automatic control devices, such as automatic flow control valves.

ballast**:** a device used in conjunction with an electric-discharge lamp to cause the lamp to start and operate under the proper circuit conditions of voltage, current, wave form, electrode heat, etc.

(a) ***electronic ballast:*** a ballast constructed using electronic circuitry.

(b) ***hybrid ballast:*** a ballast constructed using a combination of magnetic core and insulated wire winding and electronic circuitry.

(c) ***magnetic ballast:*** a ballast constructed with magnetic core and a winding of insulated wire.

baseline building design**:** a computer representation of a hypothetical design based on the proposed building project. This representation is used as the basis for calculating the *baseline building performance* for rating above-standard design.

baseline building performance**:** the annual energy cost for a building design intended for use as a baseline for rating above-standard design.

below-grade wall**:** see *wall*.

boiler**:** a closed vessel used for heating water or liquid, or for generating steam or vapor by direct application of heat from combustible fuels or electricity.

branch circuit**:** the circuit conductors between the final over-current device protecting the circuit and the outlet(s); the final wiring run to the load.

budget building design**:** a computer representation of a hypothetical design based on the actual proposed building design. This representation is used as the basis for calculating the energy cost budget.

building**:** a structure wholly or partially enclosed within exterior walls, or within exterior and party walls, and a roof, affording shelter to persons, animals, or property.

building entrance**:** any doorway, set of doors, turnstiles, or other form of portal that is ordinarily used to gain access to the building by its users and occupants.

building envelope**:** the exterior plus the semi-exterior portions of a building. For the purposes of determining building envelope requirements, the classifications are defined as follows:

(a) ***building envelope, exterior:*** the elements of a building that separate conditioned spaces from the exterior.

(b) ***building envelope, semi-exterior:*** the elements of a building that separate conditioned space from unconditioned space or that enclose semi heated spaces through which thermal energy may be transferred to or from the exterior, or to or from unconditioned spaces, or to or from conditioned spaces.

building exit**:** any doorway, set of doors, or other form of portal that is ordinarily used only for emergency egress or convenience exit.

building grounds lighting**:** lighting provided through a building's electrical service for parking lot, site, roadway, pedestrian pathway, loading dock, and security applications.

***building material*:** any element of the building envelope through which heat flows and that is included in the component U-factor calculations other than air films and insulation.

***building official*:** the officer or other designated representative authorized to act on behalf of the authority having jurisdiction.

C-factor (thermal conductance): time rate of steady-state heat flow through unit area of a material or construction, induced by a unit temperature difference between the body surfaces. Units of C are $Btu/h \cdot ft^2 \cdot °F$. Note that the C-factor does not include soil or air films.

***circuit breaker*:** a device designed to open and close a circuit by non automatic means and to open the circuit automatically at a predetermined over current without damage to itself when properly applied within its rating.

***class of construction*:** for the building envelope, a subcategory of roof, above-grade wall, below-grade wall, floor, slab-on-grade floor, opaque door, vertical fenestration, or skylight. (See *roof, wall, floor, slab-on-grade floor, door,* and *fenestration.*)

***clerestory*:** that part of a building that rises clear of the roofs or other parts and whose walls contain windows for lighting the interior.

***code official*:** see *building official*.

***coefficient of performance (COP)—cooling*:** the ratio of the rate of heat removal to the rate of energy input, in consistent units, for a complete refrigerating system or some specific portion of that system under designated operating conditions.

***coefficient of performance (COP), heat pump—heating*:** the ratio of the rate of heat delivered to the rate of energy input, in consistent units, for a complete heat pump system, including the compressor and, if applicable, auxiliary heat, under designated operating conditions.

***conditioned floor area*:** see *floor area*.

***conditioned space*:** see *space*.

***conductance*:** see *thermal conductance*.

continuous insulation (ci): insulation that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior, exterior, or is integral to any opaque surface of the building envelope.

***control*:** to regulate the operation of equipment.

***control device*:** a specialized device used to regulate the operation of equipment.

***construction*:** the fabrication and erection of a new building or any addition to or alteration of an existing building.

***construction documents*:** drawings and specifications used to construct a building, building systems, or portions thereof.

***cool down*:** reduction of space temperature down to occupied setpoint after a period of shutdown or setup.

***cooled space*:** see *space*.

***cooling degree-day*:** see *degree-day*.

***cooling design temperature*:** the outdoor dry-bulb temperature equal to the temperature that is exceeded 1% of the number of hours during a typical weather year.

***cooling design wet-bulb temperature*:** the outdoor wet-bulb temperature for sizing cooling systems and evaporative heat rejection systems such as cooling towers.

***dead band*:** the range of values within which a sensed variable can vary without initiating a change in the controlled process.

***decorative lighting*:** see *lighting, decorative*.

***degree-day*:** the difference in temperature between the outdoor mean temperature over a 24-hour period and a given base temperature. For the purposes of determining building envelope requirements, the classifications are defined as follows**:**

(a) ***cooling degree-day base 50°F, CDD50:*** for any one day, when the mean temperature is more than 50°F, there are as many degree-days as degrees Fahrenheit temperature difference between the mean temperature for the day and 50°F. Annual cooling degree-days (CDDs) are the sum of the degree-days over a calendar year.

(b) ***heating degree-day base 65°F, HDD65:*** for any one day, when the mean temperature is less than 65°F, there are as many degree-days as degrees Fahrenheit temperature difference between the mean temperature for the day and 65°F. Annual heating degree-days (HDDs) are the sum of the degree-days over a calendar year demand: the highest amount of power (average Btu/h over an interval) recorded for a building or facility in a selected time frame.

***design capacity*:** output capacity of a system or piece of equipment at design conditions.

***design conditions*:** specified environmental conditions, such as temperature and light intensity, required to be produced and maintained by a system and under which the system must operate.

***design energy cost*:** the annual energy cost calculated for a proposed design.

***design professional*:** an architect or engineer licensed to practice in accordance with applicable state licensing laws.

direct digital control (DDC): a type of control where controlled and monitored analog or binary data (e.g., temperature, contact closures) are converted to digital format for manipulation and calculations by a digital computer or microprocessor, then converted back to analog or binary form to control physical devices.

***disconnect*:** a device or group of devices or other means by which the conductors of a circuit can be disconnected from their source of supply.

door**:** all operable opening areas (which are not fenestration) in the building envelope, including swinging and roll-up doors, fire doors, and access hatches. Doors that are more than one-half glass are considered fenestration. (See *fenestration*.) For the purposes of determining building envelope requirements, the classifications are defined as follows:

(a) ***non-swinging:*** roll-up, sliding, and all other doors that are not swinging doors.

(b) ***swinging:*** all operable opaque panels with hinges on one side and opaque revolving doors.

door area**:** total area of the door measured using the rough opening and including the door slab and the frame. (See fenestration area.)

duct: any tube or conduit for transmission of air. This definition shall not include:

(a) a vent, a vent connector or a chimney connector.

(b) any tube or conduit wherein the pressure of the air exceeds one (1) pound per square inch.

(c) the air passages of listed self-contained systems.

duct system: all ducts, duct fittings, plenums and fans assembled to form a continuous passageway for the distribution of air.

dwelling unit**:** a single unit providing complete independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, cooking, and sanitation.

economizer, air**:** a duct and damper arrangement and automatic control system that together allow a cooling system to supply *outdoor air* to reduce or eliminate the need for mechanical cooling during mild or cold weather.

economizer, water**:** a system by which the supply air of a cooling system is cooled indirectly with water that is itself cooled by heat or mass transfer to the environment without the use of mechanical cooling.

efficiency**:** performance at specified rating conditions.

emittance**:** the ratio of the radiant heat flux emitted by a specimen to that emitted by a blackbody at the same temperature and under the same conditions.

enclosed space**:** a volume substantially surrounded by solid surfaces such as walls, floors, roofs, and openable devices such as doors and operable windows.

energy**:** the capacity for doing work. It takes a number of forms that may be transformed from one into another such as thermal (heat), mechanical (work), electrical, and chemical. Customary measurement units are British thermal units (Btu).

energy cost budget**:** the annual energy cost for the budget building design intended for use in determining minimum compliance with this code.

energy efficiency ratio (EER): the ratio of net cooling capacity in Btu/h to total rate of electric input in watts under designated operating conditions. (See *coefficient of performance (COP)—cooling*.)

energy factor (EF): a measure of water heater overall *efficiency*.

envelope performance factor**:** the trade-off value for the building envelope performance compliance option calculated using the procedures specified in Section 5. For the purposes of determining building envelope requirements, the classifications are defined as follows:

(a) ***base envelope performance factor:*** the building envelope performance factor for the base design.

(b) ***proposed envelope performance factor:*** the building envelope performance factor for the proposed design.

equipment**:** devices for comfort conditioning, electric power, lighting, transportation, or service water heating including, but not limited to, furnaces, boilers, air conditioners, heat pumps, chillers, water heaters, lamps, luminaires, ballasts, elevators, escalators, or other devices or installations.

existing building**:** a building or portion thereof that was previously occupied or approved for occupancy by the authority having jurisdiction.

existing equipment**:** equipment previously installed in an existing building.

existing system**:** a system or systems previously installed in an existing building.

exterior building envelope**:** see *building envelope*.

exterior lighting power allowance**:** see *lighting power allowance*.

F-factor**:** the perimeter heat loss factor for slab-on-grade floors, expressed in Btu/h·ft·°F.

facade area**:** area of the facade, including overhanging soffits, cornices, and protruding columns, measured in elevation in a vertical plane parallel to the plane of the face of the building. Nonhorizontal roof surfaces shall be included in the calculation of vertical facade area by measuring the area in a plane parallel to the surface.

fan system power**:** the sum of the nominal power demand (nameplate horsepower) of motors of all fans that are required to operate at design conditions to supply air from the heating or cooling source to the conditioned space(s) and return it to the source or exhaust it to the outdoors.

feeder conductors**:** the wires that connect the service equipment to the branch circuit breaker panels.

fenestration**:** all areas (including the frames) in the building envelope that let in light, including windows, plastic panels, clerestories, skylights, glass doors that are more than one-half glass, and glass block walls. (See *building envelope* and *door*.)

(a) ***skylight*****:** a fenestration surface having a slope of less than 60 degrees from the horizontal plane. Other fenestration, even if mounted on the roof of a building, is **considered vertical fenestration.**

(b) ***vertical fenestration*****:** all fenestration other than skylights. Trombe wall assemblies, where glazing is installed within 12 in. of a mass wall, are considered walls, not fenestration. fenestration area: total area of the fenestration measured using the rough opening and including the glazing, sash, and frame. For doors where the glazed vision area is less than 50% of the door area, the fenestration area is the glazed vision area. For all other doors, the fenestration area is the door area. (See *door area*.)

fenestration area: total area of the fenestration measured using the rough opening and including the glazing, sash, and frame. For doors where the glazed vision area is less than 50% of the door area, the fenestration area is the glazed vision area. For all other doors, the fenestration area is the door area. (See *door area*.)

fenestration, vertical**:** (See *fenestration* and *skylight*.)

fixture**:** the component of a luminaire that houses the lamp or lamps, positions the lamp, shields it from view, and distributes the light. The fixture also provides for connection to the power supply, which may require the use of a ballast.

floor, envelope**:** that lower portion of the building envelope, including opaque area and fenestration, that has conditioned or semiheated space above and is horizontal or tilted at an angle of less than 60 degrees from horizontal but excluding slab-on-grade floors. For the purposes of determining building envelope requirements, the classifications are defined as follows:

(a) ***mass floor:*** a floor with a heat capacity that exceeds (1) 7 Btu/ft^2·°F or (2) 5 Btu/ft^2·°F provided that the floor has a material unit mass not greater than 120 lb/ft^3.

(b) ***steel-joist floor*****:** a floor that (1) is not a mass floor and (2) that has steel joist members supported by structural members.

(c) ***wood-framed and other floors*****:** all other floor types, including wood joist floors. (See *building envelope*, *fenestration*, *opaque area*, and *slab-on-grade floor*).

floor area, gross**:** the sum of the floor areas of the spaces within the building including basements, mezzanine and inter-mediate-floored tiers, and penthouses with headroom height of 7.5 ft or greater. It is measured from the exterior faces of exterior walls or from the centerline of walls separating buildings, but excluding covered walkways, open roofed-over areas, porches and similar spaces, pipe trenches, exterior terraces or steps, chimneys, roof overhangs, and similar features.

(a) ***gross building envelope floor area:*** the gross floor area of the building envelope, but excluding slab-on-grade floors.

(b) ***gross conditioned floor area:*** the gross floor area of conditioned spaces.

(c) ***gross lighted floor area:*** the gross floor area of lighted spaces.

(d) ***gross semiheated floor area:*** the gross floor area of semi-heated spaces. (See *building envelope*, *floor*, *slab-on-grade floor*, and *space*.)

flue damper**:** a device in the flue outlet or in the inlet of or upstream of the draft control device of an individual, automatically operated, fossil fuel-fired appliance that is designed to automatically open the flue outlet during appliance operation and to automatically close the flue outlet when the appliance is in a standby condition.

fossil fuel**:** fuel derived from a hydrocarbon deposit such as petroleum, coal, or natural gas derived from living matter of a previous geologic time.

fuel**:** a material that may be used to produce heat or generate power by combustion.

general lighting**:** see lighting, general.

generally accepted engineering standard**:** a specification, rule, guide, or procedure in the field of engineering, or related thereto, recognized and accepted as authoritative.

grade**:** the finished ground level adjoining a building at all exterior walls.

gross lighted area (GLA): see *floor area*, *gross*: *gross lighted floor area*.

gross roof area**:** see *roof area*, *gross*.

gross wall area**:** see *wall area*, *gross*.

heat capacity (HC): the amount of heat necessary to raise the temperature of a given mass 1°F. Numerically, the heat capacity per unit area of surface (Btu/ft^2·°F) is the sum of the products of the mass per unit area of each individual material in the roof, wall, or floor surface multiplied by its individual specific heat.

heated space**:** *see space*.

heat trace**:** a heating system where the externally applied heat source follows (traces) the object to be heated, e.g., water piping.

heating design temperature**:** the outdoor dry-bulb temperature equal to the temperature that is exceeded at least 99.6% of the number of hours during a typical weather year.

heating degree-day**:** see *degree-day*.

heating seasonal performance factor (HSPF**):** the total heating output of a heat pump during its normal annual usage period for heating (in Btu) divided by the total electric energy input during the same period.

historic**:** a building or space that has been specifically designated as historically significant by the adopting authority or is listed in "The National Register of Historic Places" or has been determined to be eligible for listing by the U.S. Secretary of the Interior.

humidistat**:** an automatic control device used to maintain humidity at a fixed or adjustable setpoint.

HVAC system: the equipment, distribution systems, and terminals that provide, either collectively or individually, the processes of heating ventilating, or air conditioning to a building or portion of a building.

indirectly conditioned space**:** see *space*.

infiltration**:** the uncontrolled inward air leakage through cracks and crevices in any building element and around windows and doors of a building caused by pressure differences across these elements due to factors such as wind, inside and outside temperature differences (stack effect), and imbalance between supply and exhaust air systems.

installed interior lighting power**:** the power in watts of all permanently installed general, task, and furniture lighting systems and luminaires.

integrated part-load value (IPLV): a single-number figure of merit based on part-load EER, COP, or kW/ton expressing part-load efficiency for air-conditioning and heat pump equipment on the basis of weighted operation at various load capacities for the equipment.

interior lighting power allowance**:** see *lighting power allowance*.

isolation devices**:** devices that isolate HVAC zones so that they can be operated independently of one another. Isolation devices include, but are not limited to, separate systems, isolation dampers, and controls providing shutoff at terminal boxes.

joist, steel**:** any structural steel member of a building or structure made of hot-rolled or cold-rolled solid or open-web sections.

kilovolt-ampere (kVA)**:** where the term "kilovolt-ampere" (kVA) is used in this code, it is the product of the line current (amperes) times the nominal system voltage (kilovolts) times 1.732 for three-phase currents. For single-phase applications, kVA is the product of the line current (amperes) times the nominal system voltage (kilovolts).

kilowatt (kW)**:** the basic unit of electric power, equal to 1000 W.

labeled**:** equipment or materials to which a symbol or other identifying mark has been attached by the manufacturer indicating compliance with specified standards or performance in a specified manner.

lamp: a generic term for a man-made light source often called a bulb or tube.

(a) ***compact fluorescent lamp:*** a fluorescent lamp of a small compact shape, with a single base that provides the entire mechanical support function.

(b) ***fluorescent lamp:*** a low-pressure electric discharge lamp in which a phosphor coating transforms some of the ultraviolet energy generated by the discharge into light.

(c) ***general service lamp:*** a class of incandescent lamps that provide light in virtually all directions. General service lamps are typically characterized by bulb shapes such as A, standard; S, straight side; F, flame; G, globe; and PS, pear straight.

(d) ***high-intensity discharge (HID) lamp:*** an electric discharge lamp in that light is produced when an electric arc is discharged through a vaporized metal such as mercury or sodium. Some HID lamps may also have a phosphor coating that contributes to the light produced or enhances the light color.

(e) ***incandescent lamp:*** a lamp in which light is produced by a filament heated to incandescence by an electric current.

(f) ***reflector lamp:*** a class of incandescent lamps that have an internal reflector to direct the light. Reflector lamps are typically characterized by reflective characteristics such as R, reflector; ER, ellipsoidal reflector; PAR, parabolic aluminized reflector; MR, mirrorized reflector; and others.

lighting, decorative**:** lighting that is purely ornamental and installed for aesthetic effect. Decorative lighting shall not include general lighting.

lighting, general**:** lighting that provides a substantially uniform level of illumination throughout an area. General lighting shall not include decorative lighting or lighting that provides a dissimilar level of illumination to serve a specialized application or feature within such area.

lighting system**:** a group of luminaires circuited or controlled to perform a specific function.

lighting power allowance**:**

(a) ***interior lighting power allowance:*** the maximum lighting power in watts allowed for the interior of a building.

(b) ***exterior lighting power allowance:*** the maximum lighting power in watts allowed for the exterior of a building.

lighting power density (LPD): the maximum lighting power per unit area of a building classification of space function.

low-rise residential**:** single-family houses, multi-family structures of three stories or fewer above grade, manufactured houses (mobile homes), and manufactured houses (modular).

luminaire**:** a complete lighting unit consisting of a lamp or lamps together with the housing designed to distribute the light, position and protect the lamps, and connect the lamps to the power supply.

manual (nonautomatic): requiring personal intervention for control. Nonautomatic does not necessarily imply a manual controller, only that personal intervention is necessary. (See automatic.)

manufacturer**:** the company engaged in the original production and assembly of products or equipment or a company that purchases such products and equipment manufactured in accordance with company specifications.

***mass wall*:** see *wall*.

***mean temperature*:** one-half the sum of the minimum daily temperature and maximum daily temperature.

***Mechanical Code*:** the *City of Houston Mechanical Code*, as adopted by the *authority having jurisdiction*.

***mechanical heating*:** raising the temperature of a gas or liquid by use of fossil fuel burners, electric resistance heaters, heat pumps, or other systems that require energy to operate.

***mechanical cooling*:** reducing the temperature of a gas or liquid by using vapor compression, absorption, desiccant dehumidification combined with evaporative cooling, or another energy-driven thermodynamic cycle. Indirect or direct evaporative cooling alone is not considered mechanical cooling.

***metal building*:** a complete integrated set of mutually dependent components and assemblies that form a building, which consists of a steel-framed superstructure and metal skin.

***metal building roof*:** see *roof*.

***metal building wall*:** see *wall*.

***metering*:** instruments that measure electric voltage, current, power, etc.

***motor power, rated*:** the rated output power from the motor.

***nameplate rating*:** the design load operating conditions of a device as shown by the manufacturer on the nameplate or otherwise marked on the device.

***nonautomatic*:** see *manual*.

***nonrecirculating system*:** a domestic or service hot water distribution system that is not a recirculating system.

***nonrenewable energy*:** energy derived from a fossil fuel source.

***nonresidential*:** all occupancies other than residential. (See residential.)

nonstandard part-load value (NPLV): a single-number part-load efficiency figure of merit calculated and referenced to conditions other than IPLV conditions, for units that are not designed to operate at ARI Standard Rating Conditions.

***non-swinging door*:** see *door*.

***north-oriented*:** facing within 45 degrees of true north (northern hemisphere).

***occupant sensor*:** a device that detects the presence or absence of people within an area and causes lighting, equipment, or appliances to be regulated accordingly.

***opaque*:** all areas in the building envelope, except fenestration and building service openings such as vents and grilles. (See *building envelope* and *fenestration*.)

***optimum start controls*:** controls that are designed to automatically adjust the start time of an HVAC system each day with the intention of bringing the space to desired occupied temperature levels immediately before scheduled occupancy.

***orientation*:** the direction an envelope element faces, i.e., the direction of a vector perpendicular to and pointing away from the surface outside of the element. For vertical fenestration, the two categories are north-oriented and all other. (See north-oriented.)

***outdoor (outside) air*:** air that is outside the building envelope or is taken from outside the building that has not been previously circulated through the building.

***overcurrent*:** any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fault.

***packaged terminal air conditioner (PTAC)*:** a factory-selected wall sleeve and separate unencased combination of heating and cooling components, assemblies, or sections. It may include heating capability by hot water, steam, or electricity and is intended for mounting through the wall to serve a single room or zone.

***packaged terminal heat pump (PTHP)*:** a PTAC capable of using the refrigerating system in a reverse cycle or heat pump mode to provide heat.

***party wall*:** a fire wall on an interior lot line used or adapted for joint service between two buildings.

***performance rating method*:** a calculation procedure that generates an index of merit for the performance of building designs that substantially exceeds the energy efficiency levels required by this code.

***permanently installed*:** equipment that is fixed in place and is not portable or movable.

***plenum*:** a compartment or chamber to which one or more ducts are connected, that forms a part of the air distribution system, and that is not used for occupancy or storage. A plenum often is formed in part or in total by portions of the building.

***pool*:** any structure, basin, or tank containing an artificial body of water for swimming, diving, or recreational bathing. The term includes, but is not limited to, swimming pool, whirlpool, spa, hot tub.

***process energy*:** energy consumed in support of a manufacturing, industrial, or commercial process other than conditioning spaces and maintaining comfort for the human occupants of a building.

***projection factor (PF)*:** the ratio of the horizontal depth of the external shading projection divided by the sum of the height of the fenestration and the distance from the top of the fenestration to the bottom of the farthest point of the external shading projection, in consistent units.

***proposed building performance*:** the annual energy cost calculated for a proposed design.

***proposed design*:** a computer representation of the actual proposed building design or portion thereof used as the basis for calculating the design energy cost.

***public facility restroom*:** a restroom used by the transient public.

***pump system power*:** the sum of the nominal power demand (nameplate horsepower) of motors of all pumps that are required to operate at design conditions to supply fluid from the heating or cooling source to all heat transfer devices (e.g., coils, heat exchanger) and return it to the source.

***purchased energy rates*:** costs for units of energy or power purchased at the building site. These costs may include energy costs as well as costs for power demand as determined by the adopting authority.

***radiant heating system*:** a heating system that transfers heat to objects and surfaces within the heated space primarily (greater than 50%) by infrared radiation.

***rated lamp wattage*:** see *lamp wattage*, *rated*.

***rated motor power*:** see *motor power*, *rated*.

***rated R-value of insulation*:** the thermal resistance of the insulation alone as specified by the manufacturer in units of $h \cdot ft^2 \cdot °F/Btu$ at a mean temperature of 75°F. Rated R-value refers to the thermal resistance of the added insulation in framing cavities or insulated sheathing only and does not include the thermal resistance of other building materials or air films. (See *thermal resistance*.)

***rating authority*:** the organization or agency that adopts or sanctions use of this rating methodology.

***readily accessible*:** capable of being reached quickly for operation, renewal, or inspections without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, chairs, etc. In public facilities, accessibility may be limited to certified personnel through locking covers or by placing equipment in locked rooms.

***recirculating system*:** a domestic or service hot water distribution system that includes a closed circulation circuit designed to maintain usage temperatures in hot water pipes near terminal devices (e.g., lavatory faucets, shower heads) in order to reduce the time required to obtain hot water when the terminal device valve is opened. The motive force for circulation is either natural (due to water density variations with temperature) or mechanical (recirculation pump).

***recooling*:** lowering the temperature of air that has been previously heated by a mechanical heating system.

***record drawings*:** drawings that record the conditions of the project as constructed. These include any refinements of the construction or bid documents.

***reflectance*:** the ratio of the light reflected by a surface to the light incident upon it.

***reheating*:** raising the temperature of air that has been previously cooled either by mechanical refrigeration or an economizer system.

***repair*:** the reconstruction or renewal of any part of an existing building for the purpose of its maintenance.

***resistance, electric*:** the property of an electric circuit or of any object used as part of an electric circuit that determines for a given circuit the rate at which electric energy is converted into heat or radiant energy and that has a value such that the product of the resistance and the square of the current gives the rate of conversion of energy.

***reset*:** automatic adjustment of the controller set point to a higher or lower value.

***residential*:** spaces in buildings used primarily for living and sleeping. Residential spaces include, but are not limited to, dwelling units, hotel/motel guest rooms, dormitories, nursing homes, patient rooms in hospitals, lodging houses, fraternity/sorority houses, hostels, prisons, and fire stations.

***roof*:** the upper portion of the building envelope, including opaque areas and fenestration, that is horizontal or tilted at an angle of less than 60° from horizontal. For the purposes of determining building envelope requirements, the classifications are defined as follows:

(a) ***attic and other roofs:*** all other roofs, including roofs with insulation entirely below (inside of) the roof structure (i.e., attics, cathedral ceilings, and single-rafter ceilings), roofs with insulation both above and below the roof structure, and roofs without insulation but excluding metal building roofs.

(b) ***metal building roof:*** a roof that is constructed with:

  1. a metal, structural, weathering surface,
  2. has no ventilated cavity, and
  3. has the insulation entirely below deck (i.e., does not include composite concrete and metal deck construction nor a roof framing system that is separated from the superstructure by a wood substrate) and whose structure consists of one or more of the following configurations:

    (a) metal roofing in direct contact with the steel framing members or

    (b) insulation between the metal roofing and the steel framing members or

    (c) insulated metal roofing panels installed as described in 1 or 2.

(c) ***roof with insulation entirely above deck:*** a roof with all insulation:

  1. installed above (outside of) the roof structure and
  2. continuous (i.e., uninterrupted by framing members).

(d) ***single-rafter roof*:** a subcategory of attic roofs where the roof above and the ceiling below are both attached to the same wood rafter and where insulation is located in the space between these wood rafters.

***roof area, gross*:** the area of the roof measured from the exterior faces of walls or from the centerline of party walls. (See *roof* and *wall*.)

room air conditioner**:** an encased assembly designed as a unit to be mounted in a window or through a wall, or as a console. It is designed primarily to provide direct delivery of conditioned air to an enclosed space, room, or zone. It includes a prime source of refrigeration for cooling and dehumidification and a means for circulating and cleaning air. It may also include a means for ventilating and heating.

room cavity ratio (RCR): a factor that characterizes room configuration as a ratio between the walls and ceiling and is based upon room dimensions.

seasonal coefficient of performance—cooling (SCOPC): the total cooling output of an air conditioner during its normal annual usage period for cooling divided by the total electric energy input during the same period in consistent units (analogous to the SEER but for I-P or other consistent units).

seasonal coefficient of performance—heating (SCOPH): the total heating output of a heat pump during its normal annual usage period for heating divided by the total electric energy input during the same period in consistent units (analogous to the HSPF but for I-P or other consistent units).

seasonal energy efficiency ratio (SEER): the total cooling output of an air conditioner during its normal annual usage period for cooling (in Btu) divided by the total electric energy input during the same period (in Wh).

semi-exterior building envelope**:** see *building envelope*.

semiheated floor area**:** see *floor area*.

semiheated space**:** see *space*.

service**:** the equipment for delivering energy from the supply or distribution system to the premises served.

service agency**:** an agency capable of providing calibration, testing, or manufacture of equipment, instrumentation, metering, or control apparatus, such as a contractor, laboratory, or manufacturer.

service equipment**:** the necessary equipment, usually consisting of a circuit breaker or switch and fuses and accessories, located near the point of entrance of supply conductors to a building or other structure (or an otherwise defined area) and intended to constitute the main control and means of cutoff of the supply. Service equipment may consist of circuit breakers or fused switches provided to disconnect all under-grounded conductors in a building or other structure from the service-entrance conductors.

service water heating**:** heating water for domestic or commercial purposes other than space heating and process requirements.

setback**:** reduction of heating (by reducing the set point) or cooling (by increasing the set point) during hours when a building is unoccupied or during periods when lesser demand is acceptable.

setpoint**:** point at which the desired temperature (°F) of the heated or cooled space is set.

shading coefficient (SC): the ratio of solar heat gain at normal incidence through glazing to that occurring through 1/8 in. thick clear, double-strength glass. Shading coefficient, as used herein, does not include interior, exterior, or integral shading devices.

simulation program**:** a computer program that is capable of simulating the energy performance of building systems.

single-line diagram**:** a simplified schematic drawing that shows the connection between two or more items. Common multiple connections are shown as one line.

single-rafter roof**:** see *roof.*

single-zone system**:** an HVAC system serving a single HVAC zone.

site-recovered energy**:** waste energy recovered at the building site that is used to offset consumption of purchased fuel or electrical energy supplies.

site-solar energy**:** thermal, chemical, or electrical energy derived from direct conversion of incident solar radiation at the building site and used to offset consumption of purchased fuel or electrical energy supplies. For the purposes of applying this code, site-solar energy shall not include passive heat gain through fenestration systems.

skylight**:** see *fenestration.*

skylight well**:** the shaft from the skylight to the ceiling.

slab-on-grade floor**:** that portion of a slab floor of the building envelope that is in contact with the ground and that is either above grade or is less than or equal to 24 in. below the final elevation of the nearest exterior grade.

(a) ***heated slab-on-grade floor*****:** a slab-on-grade floor with a heating source either within or below it.

(b) ***unheated slab-on-grade floor*****:** a slab-on-grade floor that is not a heated slab-on-grade floor.

solar energy source**:** source of thermal, chemical, or electrical energy derived from direct conversion of incident solar radiation at the building site.

solar heat gain coefficient (SHGC): the ratio of the solar heat gain entering the space through the fenestration area to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation, which is then reradiated, conducted, or convected into the space. (See *fenestration area*.)

space**:** an enclosed space within a building. The classifications of spaces are as follows for the purpose of determining building envelope requirements.

(a) ***conditioned space*****:** a cooled space, heated space, or indirectly conditioned space defined as follows.

1. ***cooled space*****:** an enclosed space within a building that is cooled by a cooling system whose sensible output capacity exceeds 5 Btu/h·ft^2 of floor area.

2. ***heated space*****:** an enclosed space within a building that is heated by a heating system whose output

capacity relative to the floor area is greater than or equal to 5 Btu/h·ft^2.

3. ***indirectly conditioned space*****:** an enclosed space within a building that is not a heated space or a cooled space, which is heated or cooled indirectly by being connected to adjacent space(s) provided:

   (a) the product of the U-factor(s) and surface area(s) of the space adjacent to connected space(s) exceeds the combined sum of the product of the U-factor(s) and surface area(s) of the space adjoining the outdoors, unconditioned spaces, and to or from semiheated spaces (e.g., corridors) or

   (b) that air from heated or cooled spaces is intentionally transferred (naturally or mechanically) into the space at a rate exceeding 3 air changes per hour (ACH) (e.g., atria).

(b) ***semiheated space*****:** an enclosed space within a building that is heated by a heating system whose output capacity is greater than or equal to 3.4 Btu/h·ft^2 of floor area but is not a conditioned space.

(c) ***unconditioned space*****:** an enclosed space within a building that is not a conditioned space or a semiheated space. Crawlspaces, attics, and parking garages with natural or mechanical ventilation are not considered enclosed.

space-conditioning category:

(a) nonresidential conditioned space,

(b) residential conditioned space, and

(c) nonresidential and residential semiheated space. (See *nonresidential*, *residential*, and *space*.)

steel-framed wall**:** see *wall*.

steel-joist floor**:** see *floor*.

story**:** portion of a building that is between one finished floor level and the next higher finished floor level or the roof, provided, however, that a basement or cellar shall not be considered a story.

substantial contact**:** a condition where adjacent building materials are placed so that proximal surfaces are contiguous, being installed and supported so they eliminate voids between materials without compressing or degrading the thermal performance of either product.

swinging door**:** see *door*.

system**:** a combination of equipment and auxiliary devices (e.g., controls, accessories, interconnecting means, and terminal elements) by which energy is transformed so it performs a specific function such as HVAC, service water heating, or lighting.

system, existing**:** a system or systems previously installed in an existing building.

tandem wiring**:** pairs of luminaires operating with lamps in each luminaire powered from a single ballast contained in one of the luminaires.

terminal**:** a device by which energy from a system is finally delivered, e.g., registers, diffusers, lighting fixtures, faucets, etc.

thermal block**:** a collection of one or more HVAC zones grouped together for simulation purposes. Spaces need not be contiguous to be combined within a single thermal block.

thermal conductance**:** see *C-factor*.

thermal resistance (R-value): the reciprocal of the time rate of heat flow through a unit area induced by a unit temperature difference between two defined surfaces of material or construction under steady-state conditions. Units of R are h·ft^2·°F/Btu.

thermostat**:** an automatic control device used to maintain temperature at a fixed or adjustable setpoint.

thermostatic control**:** an automatic control device or system used to maintain temperature at a fixed or adjustable setpoint.

tinted**:** (as applied to fenestration) bronze, green, blue, or gray coloring that is integral with the glazing material, Tinting does not include surface applied films such as reflective coatings, applied either in the field or during the manufacturing process.

transformer**:** a piece of electrical equipment used to convert electric power from one voltage to another voltage.

(a) ***dry-type transformer:*** a transformer in which the core and coils are in a gaseous or dry compound.

(b) ***liquid-immersed transformer:*** a transformer in which the core and coils are immersed in an insulating liquid.

U-factor (thermal transmittance): heat transmission in unit time through unit area of a material or construction and the boundary air films, induced by unit temperature difference between the environments on each side. Units of U are Btu/h·ft^2·°F.

unconditioned space**:** see *space*.

unenclosed space**:** a space that is not an enclosed space.

unitary cooling equipment**:** one or more factory-made assemblies that normally include an evaporator or cooling coil and a compressor and condenser combination. Units that perform a heating function are also included.

unitary heat pump**:** one or more factory-made assemblies that normally include an indoor conditioning coil, compressor(s), and an outdoor refrigerant-to-air coil or refrigerant-to-water heat exchanger. These units provide both heating and cooling functions.

variable air volume (VAV) system**:** HVAC system that controls the dry-bulb temperature within a space by varying the volumetric flow of heated or cooled supply air to the space.

vent damper**:** a device intended for installation in the venting system of an individual, automatically operated, fossil fuel-fired appliance in the outlet or downstream of the appliance draft control device, which is designed to automatically open the venting system when the appliance is in operation and to automatically close off the venting system when the appliance is in a standby or shutdown condition.

ventilation**:** the process of supplying or removing air by natural or mechanical means to or from any space. Such air is not required to have been conditioned.

vertical fenestration**:** see *fenestration*.

voltage drop**:** a decrease in voltage caused by losses in the lines connecting the power source to the load.

wall**:** that portion of the building envelope, including opaque area and fenestration, that is vertical or tilted at an angle of 60° from horizontal or greater. This includes above- and below-grade walls, between floor spandrels, peripheral edges of floors, and foundation walls. For the purposes of determining building envelope requirements, the classifications are defined as follows:

(a) ***above-grade wall:*** a wall that is not a below-grade wall.

(b) ***below-grade wall:*** that portion of a wall in the building envelope that is entirely below the finish grade and in contact with the ground.

(c) ***mass wall:*** a wall with a heat capacity exceeding (1) 7 $Btu/ft^2 \cdot °F$ or (2) 5 $Btu/ft^2 \cdot °F$ provided that the wall has a material unit weight not greater than 120 lb/ft^3.

(d) ***metal building wall:*** a wall whose structure consists of metal spanning members supported by steel structural members (i.e., does not include spandrel glass or metal panels in curtain wall systems).

(e) ***steel-framed wall:*** a wall with a cavity (insulated or otherwise) whose exterior surfaces are separated by steel framing members (i.e., typical steel stud walls and curtain wall systems).

(f) ***wood-framed and other walls:*** all other wall types, including wood stud walls.

wall area, gross**:** the area of the wall measured on the exterior face from the top of the floor to the bottom of the roof.

warm-up**:** increase in space temperature to occupied setpoint after a period of shutdown or setback.

water heater**:** vessel in which water is heated and is withdrawn for use external to the system.

wood-framed and other walls**:** see *wall*.

wood-framed and other floors**:** see *floor*.

zone, HVAC**:** a space or group of spaces within a building with heating and cooling requirements that are sufficiently similar so that desired conditions (e.g., temperature) can be maintained throughout using a single sensor (e.g., thermostat or temperature sensor)

3.3 Abbreviations and Acronyms

Ac	alternating current
ACH	air changes per hour
AFUE	annual fuel utilization efficiency
AHAM	Association of Home Appliance Manufacturers
ANSI	American National Standards Institute
ARI	Air-Conditioning and Refrigeration Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
ASTM	American Society for Testing and Materials
BSR	Board of Standards Review
Btu	British thermal unit
Btu/h	British thermal unit per hour
Btu/ft^2·°F	British thermal unit per square foot per degree Fahrenheit
Btu/h·ft^2	British thermal unit per hour per square foot
Btu/h·ft·°F	British thermal unit per hour per lineal foot per degree Fahrenheit
Btu/h·ft^2·°F	British thermal unit per hour per square foot per degree Fahrenheit
CDD	cooling degree-day
CDD50	cooling degree-days base 50°F
cfm	cubic feet per minute
ci	continuous insulation
COP	coefficient of performance
CTI	Cooling Tower Institute
DDC	direct digital control
DOE	U.S. Department of Energy
Ec	combustion efficiency
EER	energy efficiency ratio
EF	energy factor
ENVSTD	Envelope System Performance Compliance
Et	thermal efficiency
F	Fahrenheit
Ft	foot
H	hour
HC	heat capacity
HDD	heating degree-day
HDD65	heating degree-days base 65°F
H·ft^2·°F/Btu	hour per square foot per degree Fahrenheit per British thermal unit
HID	high-intensity discharge
hp	horsepower
HSPF	heating seasonal performance factor
HVAC	heating, ventilating, and air conditioning
IESNA	Illuminating Engineering Society of North America
in.	inch
I-P	inch-pound
IPLV	integrated part-load value
K	kelvin
kVA	kilovolt-ampere
kW	kilowatt
kWh	kilowatt-hour
lb	Pound
lin	Linear
lin ft	linear foot
LPD	lighting power density
MICA	Midwest Insulation Contractors Association
NAECA	U.S. National Appliance Energy Conservation Act of 1987
NFPA	National Fire Protection Association
NFRC	National Fenestration Rating Council
NPLV	non-standard part load value
PF	projection factor
PTAC	packaged terminal air conditioner
PTHP	packaged terminal heat pump
R	R-value (thermal resistance)
R_c	thermal resistance of a material or construction from surface to surface
R_u	total thermal resistance of a material or construction from surface to surface
Rpm	revolutions per minute
SC	shading coefficient
SEER	seasonal energy efficiency ratio
SHGC	solar heat gain coefficient
SL	standby loss
SMACNA	Sheet Metal and Air Conditioning Contractors' National Association
T_{db}	dry-bulb temperature
T_{wb}	wet-bulb temperature
UL	Underwriters Laboratories Inc.
VAV	variable air volume
VLT	visible light transmittance
W	watt
W/ft^2	watts per square foot
Wh	watthour

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4. ADMINISTRATION AND ENFORCEMENT

4.1 General

4.1.1 Scope. The provisions of this code shall apply to the construction, *alteration*, movement, enlargement, replacement, repair, equipment, use and occupancy, location, maintenance, removal and demolition of buildings, as provided in Section 2 of this code.

4.1.1.1 New Buildings. New buildings shall comply with this code as described in Section 4.2.

4.1.1.2 Additions to Existing Buildings. An extension or increase in the floor area or height of a building outside of the *existing building* envelope shall be considered *additions* to *existing buildings* and shall comply with the code as described in Section 4.2.

4.1.1.3 Alterations of Existing Buildings: *Alterations* of *existing buildings* shall comply with the standard as described in Section 4.2.

4.1.1.4 Replacement of Portions of Existing Buildings: Portions of a building envelope, heating, ventilating, air-conditioning, service water heating, power, lighting, and other systems and equipment that are being replaced shall be considered as Alterations of Existing Buildings and shall comply with the code as described in Section 4.2.

4.1.1.5 Changes in Space Conditioning. Whenever *unconditioned* or *semiheated* spaces in a building are converted to *conditioned spaces*, such *conditioned spaces* shall be brought into compliance with all the applicable requirements of this code that would apply to the building envelope, heating, ventilating, air-conditioning, service water heating, power, lighting, and other systems and equipment of the space as if the building were new.

4.1.2 Administrative Requirements. Administrative requirements relating to permit requirements, enforcement by the *authority having jurisdiction*, locally adopted energy code, interpretations, claims of exemption, and rights of appeal shall be as set forth in the applicable volume of the City of Houston Construction Code.

4.1.3 Alternative Materials, Methods of Construction, or Design. The provisions of this code are not intended to prevent the use of any material, method of construction, design, equipment, or building system not specifically prescribed herein.

4.1.4 Reserved.

4.1.5 Reserved.

4.1.6 Referenced Standards. The standards referenced in this code and listed in Section 12 shall be considered part of the requirements of this code to the prescribed extent of such reference. Where differences occur between the provision of this code and referenced standards, the provisions of this code shall apply. Informative references are cited to acknowledge sources and are not part of this code. They are identified in Informative Appendix E.

4.1.6 Normative Appendices. The normative appendices to this code are considered to be integral parts of the mandatory requirements of this code, which for reasons of convenience, are placed apart from all other normative elements.

4.1.8 Informative Appendices. The informative appendices to this code and informative notes located within this code contain additional information and are not mandatory or part of this code.

4.2 Compliance

4.2.1 Compliance Paths

4.2.1.1 New Buildings: New Buildings shall comply with either the provisions of Sections 5, 6, 7, 8, 9, and 10 or Section 11.

4.2.1.2 Additions to Existing Buildings: *Additions* to *existing buildings* shall comply with either the provisions of Sections 5, 6, 7, 8, 9, and 10 or Section 11.

Exception to 4.2.1.2: When an addition to an *existing building* cannot comply by itself, trade-offs will be allowed by modification to one or more of the existing components of the *existing building*. Modeling of the modified components of the *existing building* and addition shall employ the procedures of Section 11; and the addition shall not increase the energy consumption of the *existing building* plus the addition beyond the energy that would be consumed by the *existing building* plus the addition if the addition alone did comply.

4.2.1.3 Alterations of Existing Buildings: *Alterations* of *existing buildings* shall comply with the provisions of Sections 5, 6, 7, 8, 9, and 10, provided, however that nothing in this code shall require compliance with any provision of this code if such compliance will result in the increase of energy consumption of the building.

Exceptions to 4.2.1.3:

(a) A *historic* building need not comply with a provision or provisions that would invalidate or jeopardize the historical designation or listing.

(b) Where one or more components of an *existing building* or portions thereof are being replaced, the annual energy consumption of the comprehensive design shall not be greater than the annual energy consumption of a substantially identical design, using the same energy types, in which the applicable requirements of Sections 5, 6, 7, 8, 9, and 10, as provided in 4.2.1.3, and such compliance is verified by a *design professional*, by the use of any calculation methods acceptable to the *authority having jurisdiction*.

4.2.2 Compliance Documentation

4.2.2.1 Construction Details. Compliance documents shall show all the pertinent data and features of the building, equipment, and systems in sufficient detail to permit a determination of compliance by the *building official* and to indicate compliance with the requirements of this code.

4.2.2.2 Supplemental Information. Supplemental information necessary to verify compliance with this code, such as calculations, worksheets, compliance forms, vendor literature, or other data, shall be made available when required by the *building official*.

4.2.2.3 Manuals. Operating and maintenance information shall be provided to the building owner. This information shall include, but not be limited to, the information specified in 6.7.2.2 and 8.7.2.

4.2.3 Labeling of Material and Equipment. Materials and equipment shall be labeled in a manner that will allow for a determination of their compliance with the applicable provisions of this code.

4.2.4 Inspections. All building construction, *additions*, or *alterations* subject to the provisions of this code shall be subject to inspection by the *building official*, and all such work shall remain accessible and exposed for inspection purposes until approved in accordance with the procedures specified by the *building official*. Items for inspection include at least the following:

(a) wall insulation after the insulation and vapor retarder are in place but before concealment,

(b) roof/ceiling insulation after roof/insulation is in place but before concealment,

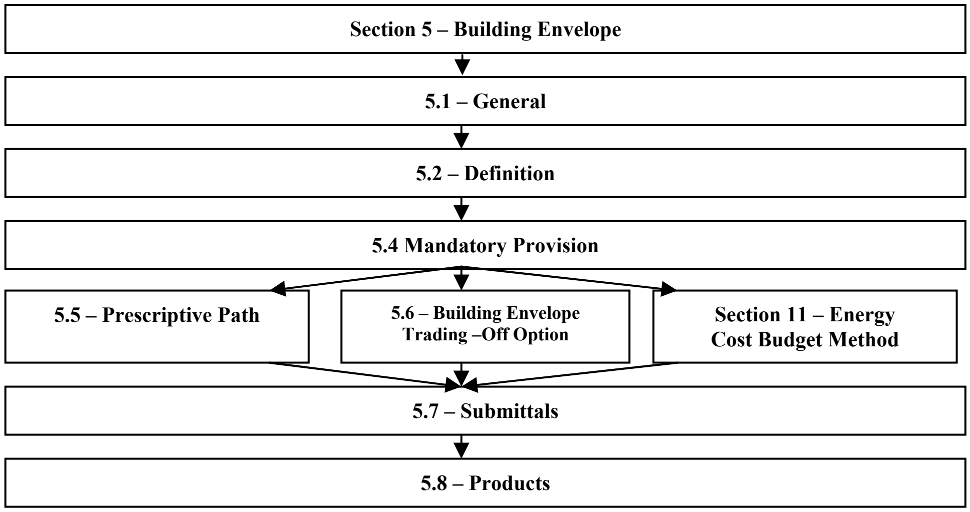
(c) slab/foundation wall after slab/foundation insulation is in place but before concealment,

(d) fenestration after all glazing materials are in place,

(e) mechanical systems and equipment and insulation after installation but before concealment,

(f) electrical equipment and systems after installation but before concealment.

5. BUILDING ENVELOPE



5.1 General

5.1.1 Scope. Section 5 specifies requirements for the *building envelope*.

5.1.2 Space-Conditioning Categories.

5.1.2.1 Separate *exterior building envelope* requirements are specified for each of three categories of conditioned space:

(a) *nonresidential conditioned* space,

(b) *residential conditioned* space, or

(c) *semiheated* space.

5.1.2.2 *Spaces* shall be assumed to be *conditioned space* and shall comply with the requirements for *conditioned space* at the time of construction, regardless of whether mechanical or electrical equipment is included in the building permit application or installed at that time.

5.1.3 Envelope Alterations. *Alterations* to the *building envelope* shall comply with the requirements of Section 5 for insulation, air leakage, and *fenestration* applicable to those specific portions of the building that are being altered.

Exceptions to 5.1.3: The following *alterations* need not comply with these requirements, provided such *alterations* will not increase the energy usage of the building:

(a) installation of storm windows over existing glazing;

(b) replacement of glazing in existing sash and frame provided the *U-factor* and *SHGC* will be equal to or lower than before the glass replacement;

(c) *alterations* to roof/ceiling, wall, or floor cavities, which are insulated to full depth with insulation having a minimum nominal value of R-3.0/in.;

(d) *alterations* to walls and floors, where the existing structure is without framing cavities and no new framing cavities are created;

(e) replacement of a roof membrane where either the roof sheathing or roof insulation is not exposed or, if there is existing roof insulation below the roof deck;

(f) replacement of existing doors that separate conditioned space from the exterior shall not require the installation of a vestibule or revolving door, provided, however, that an existing vestibule that separates a conditioned space from the exterior shall not be removed; and

(g) replacement of existing fenestration, provided, however, that the area of the replacement fenestration does not exceed 25% of the total fenestration area of an *existing building* and that the *U-factor* and *SHGC* will be equal to or lower than before the fenestration replacement.

5.1.4 Climate Conditions. Exterior design conditions shall be as set forth in Table 5.1.4.

TABLE 5.1.4 Exterior Design Conditions

Condition	Value
Winter, Design Dry-bulb (E_F)	28°F
Summer, Design Dry-bulb	96°F
Summer, Design Wet-bulb	80°F
Degree Days Heating (base 65)	1371
Degree Days Cooling (base 50)	7357
Climate Zone	2A

5.2 Compliance Paths

5.2.1 Compliance. For the appropriate climate, *space-conditioning category*, and *class of construction*, the *building envelope* shall comply with 5.1, General; 5.4, Mandatory Provisions; 5.7, Submittals; and 5.8, Product Information and Installation Requirements; and either

(a) 5.5, Prescriptive Building Envelope Option, provided that

1. the *vertical fenestration area* does not exceed 50% of the *gross wall area* for each *space-conditioning category* and
2. the *skylight fenestration* area does not exceed 5% of the *gross roof area* for each *space-conditioning category*, or

(b) 5.6, Building Envelope Trade-Off Option.

5.2.2 Projects using the Energy Cost Budget Method (Section 11 of this code), must comply with 5.4, the mandatory provisions of this section, as a portion of that compliance path.

5.3 Simplified Building: (Not Used)

5.4 Mandatory Provisions

5.4.1 Insulation. Where insulation is required in 5.5 or 5.6, it shall comply with the requirements found in 5.8.1.1 through 5.8.1.9.

5.4.2 Fenestration and Doors. Procedures for determining *fenestration* and door performance are described in 5.8.2. Product samples used for determining *fenestration* performance shall be production line units or representative of units purchased by the consumer or contractor.

5.4.3 Air Leakage.

5.4.3.1 Building Envelope Sealing. The following areas of the *building envelope* shall be sealed, caulked, gasketed, or weather-stripped to minimize air leakage:

(a) joints around *fenestration* and *door* frames,

(b) junctions between *walls* and foundations, between *walls* at building corners, between *walls* and structural *floors* or *roofs*, and between *walls* and *roof* or *wall* panels,

(c) openings at penetrations of utility services through *roofs*, *walls*, and *floors*,

(d) site-built *fenestration* and *doors*,

(e) building assemblies used as ducts or plenums,

(f) joints, seams, and penetrations of vapor retarders,

(g) all other openings in the *building envelope*.

5.4.3.2 Fenestration and Doors. Air leakage for *fenestration* and *doors* shall be determined in accordance with NFRC 400. Air leakage shall be determined by a laboratory accredited by a nationally recognized accreditation organization, such as the National Fenestration Rating Council, and shall be *labeled* and certified by the *manufacturer*. Air leakage shall not exceed 1.0 cfm/ft^2 for glazed swinging entrance doors and for revolving doors and 0.4 cfm/ft^2 for all other products.

Exceptions to 5.4.3.2:

(a) Field-fabricated fenestration and doors.

(b) For garage *doors*, air leakage determined by test at standard test conditions in accordance with ANSI/ DASMA 105 shall be an acceptable alternate for compliance with air leakage requirements.

5.4.3.3 Loading Dock Weatherseals. Cargo *doors* and loading dock *doors* shall be equipped with weatherseals to restrict *infiltration* when vehicles are parked in the doorway.

5.4.3.4 Vestibules. A *door* that separates *conditioned space* from the exterior shall be protected with an enclosed vestibule, with all *doors* opening into and out of the vestibule equipped with self-closing devices. Vestibules shall be designed so that in passing through the vestibule it is not necessary for the interior and exterior *doors* to open at the same time. Interior and exterior *doors* shall have a minimum distance between them of not less than 7 ft when in the closed position.

Exceptions to 5.4.3.4:

(a) *Doors* in buildings less than four stories above grade.

(b) *Doors* not intended to be used as a *building entrance door*, such as mechanical or electrical equipment rooms.

(c) *Doors* opening directly from a *dwelling unit*.

(d) *Doors* that open directly from a space less than 3000 ft^2 in area.

(e) *Doors* in building entrances with revolving *doors*.

(f) *Doors* used primarily to facilitate vehicular movement or material handling and adjacent personnel doors.

5.4.3.5 Cool roofs. Low slope *roofs* up to 2:12 shall be provided with a roof covering where the exterior surface has:

(a) a minimum total solar reflectance of 0.70 when tested in accordance with one of the solar reflectance test methods listed below, and

(b) a minimum thermal emittance of 0.75 when tested in accordance with one of the thermal emittance test methods listed below.

Solar Reflectance Test Methods: ASTM C1549, ASTM E903, ASTM E1175, or ASTM E1918.

Thermal Emittance Test Methods: ASTM C835, ASTM C1371, or ASTM E408.

Exceptions to 5.4.3.5:

(a) The portion of the *roof* that is covered by a rooftop deck covering 1/3 or less of the aggregate area of the roof, or a rooftop garden, or green roof, is exempted from the requirements of this section.

(b) An area including and adjacent to rooftop photovoltaic and solar thermal equipment, totaling not more than three times the area that is covered with such equipment, is exempt from the requirements of this section.

5.5 Prescriptive Building Envelope Option:

5.5.1 For *conditioned space*, the *exterior building envelope* shall comply with either the "nonresidential" or "residential" requirements in Tables 5.5-2 for climate zone 2.

5.5.2 If a building contains any *semiheated space* or *unconditioned space*, then the *semi-exterior building envelope* shall comply with the requirements for *semiheated space* in Tables 5.5-2 for climate zone 2 (See Figure 5.5.)

5.5.3 Opaque Areas. For all opaque surfaces except doors, compliance shall be demonstrated by one of the following two methods:

1. Minimum *rated R-values of insulation* for the thermal resistance of the added insulation in framing cavities and *continuous insulation* only. Specifications listed in Normative Appendix A for each *class of construction* shall be used to determine compliance.
2. Maximum *U-factor*, *C-factor*, or *F-factor* for the entire assembly. The values for typical construction assemblies listed in Normative Appendix A shall be used to determine compliance.

   Exceptions to 5.5.3(2).

   (a) For assemblies significantly different from those in Appendix A, calculations shall be performed in accordance with the procedures required in Appendix A.

   (b) For multiple assemblies within a single *class of construction* for a single *space-conditioning category*, compliance shall be shown for either (i) the most restrictive requirement or (ii) an area-weighted average *U-factor*, *C-factor*, or *F-factor.*

5.5.3.1 Roof Insulation. All *roofs* shall comply with the insulation values specified in Table 5.5-2 for climate zone 2. Skylight curbs shall be insulated to the level of roofs with insulation entirely above deck or R-8, whichever is less.

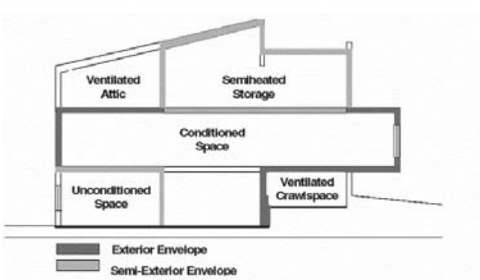


Figure 5-5 Exterior and semi-exterior building envelope

5.5.3.1.1 Reserved.

5.5.3.2 Above-Grade Wall Insulation. All *above-grade walls* shall comply with the insulation values specified in Table 5.5-2. When a *wall* consists of both *above-grade* and *below-grade* portions, the entire *wall* for that story shall be insulated on either the exterior or the interior or be integral.

(a) If insulated on the interior, the *wall* shall be insulated to the *above-grade wall* requirements.

(b) If insulated on the exterior or integral, the *below-grade wall* portion shall be insulated to the *below-grade wall* requirements, and the *above-grade wall* portion shall be insulated to the *above-grade wall* requirements.

5.5.3.3 Below-Grade Wall Insulation. *Below-grade walls* shall have a *rated R-value* of *insulation* not less that the insulation values specified in Table 5.5-2.

Exception to 5.5.3.3: Where framing, including metal and wood studs, is used, compliance shall be based on the maximum assembly *C-factor*.

5.5.3.4 Floor Insulation. All *floors* shall comply with the insulation values specified in Table 5.5-2.

5.5.3.5 Slab-on-Grade Floor Insulation. All *slab-on-grade floors*, including *heated slab-on-grade floors* and *unheated slab-on-grade floors*, shall comply with the insulation values specified in Table 5.5-2.

5.5.3.6 Opaque Doors. All *opaque doors* shall have a *U-factor* not greater than that specified in Table 5.5-2.

5.5.4 Fenestration.

5.5.4.1 General. Compliance with *U-factors* and *solar heat gain coefficient* (*SHGC*) shall be demonstrated for the overall fenestration product. Gross wall areas and gross roof areas shall be calculated separately for each *space-conditioning category* for the purposes of determining compliance.

Exception to 5.5.4.1: If there are multiple assemblies within a single *class of construction* for a single *space-conditioning category*, compliance shall be based on an area-weighted average *U-factor* or *SHGC*. It is not acceptable to do an area-weighted average across multiple *classes of construction* or multiple *space-conditioning categories.*

5.5.4.2 Fenestration Area

5.5.4.2.1 Vertical Fenestration Area. The total *vertical fenestration area* shall be less than 50% of the *gross wall area*.

Exception to 5.5.4.2.1: *Vertical fenestration* complying with Exception (c) to 5.5.4.4.1.

5.5.4.2.2 Skylight Fenestration Area. The total *skylight area* shall be less than 5% of the *gross roof area.*

5.5.4.3 Fenestration U-Factor. *Fenestration* shall have a *U-factor* not greater than that specified in Table 5.5-2 for the appropriate *fenestration area*.

Exception to 5.5.4.3: *Vertical fenestration* complying with Exception (c) to 5.5.4.4.1 shall have a *U-factor* not greater than that specified for 40% of the *gross wall area*.

5.5.4.4 Fenestration Solar Heat Gain Coefficient (SHGC).

5.5.4.4.1 SHGC of Vertical Fenestration. *Vertical fenestration* shall have a *SHGC* not greater than that specified for "all" orientations in Table 5.5-2 for the appropriate total *vertical fenestration* area.

Exceptions to 5.5.4.4.1:

(a) The *SHGC* for *north-oriented vertical fenestration* shall be calculated separately and shall not be greater than that specified in Table 5.5-2 for *north-oriented fenestration*. When this exception is used, the *fenestration area* used in selecting the criteria shall be calculated separately for *north-oriented* and all other-oriented *fenestration*.

(b) For demonstrating compliance for *vertical fenestration* only, the *SHGC* of the *fenestration* in the proposed building shall be reduced by using the multipliers in Table 5.5.4.4.1 for each *fenestration* product shaded by permanent projections when compared to the *SHGC* requirements of Table 5.5-2.

(c) *Vertical fenestration* that is located on the street side of the street-level story only, provided that:

1. the street side of the street-level story does not exceed 20 ft in height,
2. the *fenestration* has a continuous overhang with a weighted average *projection factor* greater than 0.5, and
3. the *fenestration area* for the street side of the street-level story is less than 75% of the *gross wall area* for the street side of the street-level story.

When this exception is utilized, separate calculations shall be performed for these sections of the *building envelope,* and these values shall not be averaged with any others for compliance purposes. No credit shall be given here or elsewhere in the building for not fully utilizing the *fenestration area* allowed.

TABLE 5.5.4.4.1 SHGC Multipliers for Permanent Projections

Factor Projection	SHGC Multiplier (All Other Orientations)	SHGC Multiplier (North-Oriented)
0-0.10	1.00	1.00
>0.10-0.20	0.91	0.95
>0.20-0.30	0.82	0.91
>0.30-0.40	0.74	0.87
>0.40-0.50	0.67	0.84
>0.50-0.60	0.61	0.81
>0.60-0.70	0.56	0.78
>0.70-0.80	0.51	0.76
>0.80-0.90	0.47	0.75
>0.90-1.00	0.44	0.73

5.5.4.4.2 SHGC of Skylights. *Skylights* shall have an *SHGC* not greater than that specified for "all" orientations in Table 5.5-2 for the appropriate total *skylight area*.

5.6 Building Envelope Trade-Off Option.

5.6.1 The *building envelope* complies with the code if

(a) the proposed building satisfies the provisions of 5.1, 5.4, 5.7, and 5.8, and

(b) the *envelope performance factor* of the proposed building is less than or equal to the *envelope performance factor* of the budget building.

5.6.1.1 The *envelope performance factor* considers only the *building envelope* components.

5.6.1.2 Schedules of operation, lighting power, equipment power, occupant density, and mechanical systems shall be the same for both the proposed building and the budget building.

5.6.1.3 *Envelope performance factor* shall be calculated using the procedures of Normative Appendix C.

5.7 Submittals

5.7.1 General. *Authority having jurisdiction* may require submittal of compliance documentation and supplemental information, in accordance with Section 4.2.2 of this code.

5.7.2 Submittal Document Labeling of Space Conditioning Categories. For buildings that contain spaces that will be only semiheated or unconditioned, and compliance is sought using the "semiheated" envelope criteria, such spaces shall be clearly indicated on the floor plans that are submitted for review.

5.8 Product Information and Installation Requirements

5.8.1 Insulation.

5.8.1.1 Labeling of Building Envelope Insulation. The *rated R-value* shall be clearly identified by an identification mark applied by the *manufacturer* to each piece of *building envelope* insulation.

Exception to 5.8.1.1: When insulation does not have such an identification mark, the installer of such insulation shall provide a signed and dated certification for the installed insulation listing the type of insulation, the *manufacturer*, the *rated R-value*, and, where appropriate, the initial installed thickness, the settled thickness, and the coverage area.

5.8.1.2 Compliance with Manufacturer's Requirements. Insulation materials shall be installed in accordance with *manufacturer's* recommendations and in such a manner as to achieve *rated R-value of insulation*.

Exception to 5.8.1.2: Where *metal building roof* and *metal building wall* insulation is compressed between the *roof* or *wall* skin and the structure.

5.8.1.3 Loose-fill Insulation Limitation. Open-blown or poured loose-fill insulation shall not be used in *attic roof spaces* when the slope of the ceiling is more than three in twelve.

5.8.1.4 Baffles. When eave vents are installed, baffling of the vent openings shall be provided to deflect the incoming air above the surface of the insulation.

5.8.1.5 Substantial Contact. Insulation shall be installed in a permanent manner in *substantial contact* with the inside surface in accordance with *manufacturer's* recommendations for the framing system used. Flexible batt insulation installed in floor cavities shall be supported in a permanent manner by supports no greater than 24 in. on center.

Exception to 5.8.1.5: Insulation materials that rely on air-spaces adjacent to reflective surfaces for their rated performance.

5.8.1.6 Recessed Equipment. Lighting fixtures; heating, ventilating, and air-conditioning equipment, including wall heaters, ducts, and plenums; and other equipment shall not be recessed in such a manner as to affect the insulation thickness unless:

(a) the total combined area affected (including necessary clearances) is less than one percent of the opaque area of the assembly, or

(b) the entire *roof*, *wall*, or *floor* is covered with insulation to the full depth required, or

(c) the effects of reduced insulation are included in calculations using an area-weighted average method and compressed insulation values obtained from Table A9.4.C. In all cases, air leakage through or around the recessed equipment to the *conditioned space* shall be limited in accordance with 5.4.3.

5.8.1.7 Insulation Protection. Exterior insulation shall be covered with a protective material to prevent damage from sunlight, moisture, landscaping operations, equipment maintenance, and wind.

5.8.1.7.1 In *attics* and mechanical rooms, a way to access equipment that prevents damaging or compressing the insulation shall be provided.

5.8.1.7.2 Foundation vents shall not interfere with the insulation.

5.8.1.7.3 Insulation materials in ground contact shall have a water absorption rate no greater than 0.3% when tested in accordance with ASTM C272.

5.8.1.8 Location of Roof Insulation. The *roof* insulation shall not be installed on a suspended ceiling with removable ceiling panels.

5.8.1.9 Extent of Insulation. Insulation shall extend over the full component area to the required rated R-value of insulation, U-factor, C-factor, or F-factor, unless otherwise allowed in 5.8.1.

5.8.2 Fenestration and Doors.

5.8.2.1 Rating of Fenestration Products. The U-factor, solar heat gain coefficient (SHGC), and air leakage rate for all manufactured *fenestration* products shall be determined by a laboratory accredited by a nationally recognized accreditation organization, such as the National Fenestration Rating Council.

5.8.2.2 Labeling of Fenestration Products. All manufactured *fenestration* products shall have a permanent nameplate, installed by the *manufacturer*, listing the U-factor, solar heat gain coefficient (SHGC), and air leakage rate.

Exception to 5.8.2.2: When the *fenestration* product does not have such nameplate, the installer or supplier of such *fenestration* shall provide a signed and dated certification for the installed *fenestration* listing the U-factor, SHGC, and the air leakage rate.

5.8.2.3 Labeling of Doors. The *U-factor* and the air leakage rate for all manufactured *doors* installed between *conditioned space*, *semi-heated space*, *unconditioned space*, and exterior *space* shall be identified on a permanent nameplate installed on the product by the *manufacturer*.

Exception to 5.8.2.3: When doors do not have such a nameplate, the installer or supplier of any such doors shall provide a signed and dated certification for the installed doors listing the *U-factor* and the air leakage rate.

5.8.2.4 U-factor. U-factors shall be determined in accordance with NFRC 100. U-factors for skylights shall be determined for a slope of 20 degrees above the horizontal.

Exceptions to 5.8.2.4:

(a) U-factors from A8.1 shall be an acceptable alternative for determining compliance with the U-factor criteria for *skylights*. Where credit is being taken for a low-emissivity coating, the emissivity of the coating shall be determined in accordance with NFRC 300. Emissivity shall be verified and certified by the *manufacturer*.

(b) U-factors from A8.2 shall be an acceptable alternative for determining compliance with the U-factor criteria for *vertical fenestration*.

(c) U-factors from A7 shall be an acceptable alternative for determining compliance with the U-factor criteria for *opaque doors*.

(d) For garage doors, ANSI/DASMA105 shall be an acceptable alternative for determining *U-factors*.

5.8.2.5 Solar Heat Gain Coefficient. *SHGC* for the overall *fenestration* area shall be determined in accordance with NFRC 200.

Exceptions to 5.8.2.5:

(a) *Shading coefficient* of the center of glass multiplied by 0.86 shall be an acceptable alternative for determining compliance with the *SHGC* requirements for the *overall fenestration area*. *Shading coefficient* shall be determined using a spectral data file determined in accordance with NFRC 300. *Shading coefficient* shall be verified and certified by the *manufacturer*.

(b) *SHGC* of the center of glass shall be an acceptable alternative for determining compliance with the *SHGC* requirements for the overall *fenestration area*. *SHGC* shall be determined using a spectral data file determined in accordance with NFRC 300.

SHGC shall be verified and certified by the *manufacturer*.

(c) *SHGC* from A8.1 shall be an acceptable alternative for determining compliance with the *SHGC* criteria for *skylights*. Where credit is being taken for a low-emissivity coating, the emissivity of the coating shall be determined in accordance with NFRC 300. Emissivity shall be verified and certified by the *manufacturer*.

(d) *SHGC* from A8.2 shall be an acceptable alternative for determining compliance with the *SHGC* criteria for vertical *fenestration*.

5.8.2.6 Visible Light Transmittance. Visible light transmittance shall be determined in accordance with NFRC 200. Visible light transmittance shall be verified and certified by the *manufacturer*.

5.9 Building Envelope Commissioning. For projects larger than 50,000 ft^2 conditioned area, except heated only warehouses and semiheated spaces, detailed instructions for commissioning *building envelope* systems (see Appendix E) shall be provided by the designer in plans and specifications.

TABLE 5.5-2 Building Envelope Requirements For Climate Zone 2 (A,B)*

Opaque Elements	Nonresidential		Residential		Semiheated	
	Assembly Maximum	**Insulation Min. R-Value**	**Assembly Maximum**	**Insulation Min. R-Value**	**Assembly Maximum**	**Insulation Min. R-Value**
Roofs						
Insulation Entirely above Deck	U-0.063	R-15.0 ci	U-0.063	R-15.0 ci	U-0.218	R-3.8 ci
Metal Building	U-0.065	R-19.0	U-0.065	R-38.0	U-0.167	R-13.0
Attic and Other	U-0.034	R-30.0	U-0.027	R-19.0	U-0.081	R-6.0
Walls, Above-Grade						
Mass	U-0.580	NR	U-0.089	R-5.7 ci[a]	U-0.580	NR
Metal Building	U-0.113	R-13.0	U-0.113	R-13.0	U-0.184	NR
Steel-Framed	U-0.089	R-13.0	U-0.124	R-13.0	U-0.292	NR
Wood-Framed and Other	U-0.124	R-13.0	U-0.151[a]	R-13.0	U-0.352	R-6.0
Wall, Below-Grade						
Below-Grade Wall	C-1.140	NR	C-1.140	NR	C-1.140	NR
Floors						
Mass	U-0.137	R-4.2 ci	U-0.107	R-6.3 ci	U-0.282	NR
Steel-Joist	U-0.107	R-19.0	U-0.051	R-19.0	U-0.350	NR
Wood-Framed and Other	U-0.051	R-19.0	U-0.052	R-19.0	U-0.322	NR
Slab-On-Grade Floors						
Unheated	F-1.020	NR	F-0.730	NR	F-1.020	NR
Heated	F-0.730	R-7.5 for 12 in.	F-1.020	R-7.5 for 12 in.	F-0.730	R-7.5 for 12 in.
Opaque Doors	U-0.700		U-0.700		U-0.700	
Swinging	U-1.450		U-1.450		U-1.450	
Non-Swinging						

Fenestration	Assembly Max. U (Fixed/ Operable)	Assembly Max. SHGC (All Orientations/ North-Oriented)	Assembly Max. U (Fixed/ Operable)	Assembly Max. SHGC (All Orientations/ North-Oriented)	Assembly Max. U (Fixed/ Operable)	Assembly Max. SHGC (All Orientations/ North-Oriented)
Vertical Glazing,% of Wall[b] 0-10.0%	${}^{U}oper-^{1.27}$ ${}^{U}fixed-^{1.22}$	${}^{SHGC}all-^{0.25}$ ${}^{SHGC}north-^{0.61}$	${}^{U}oper^{-1.27}$ ${}^{U}fixed^{-1.22}$	${}^{SHGC}all^{-0.39}$ ${}^{SHGC}north^{-0.61}$	${}^{U}fixed^{-1.22}$ ${}^{U}oper^{-1.27}$	${}^{SHGC}all^{-NR}$ ${}^{SHGC}north^{NR}$
10.1-20.0%	${}^{U}fixed^{-1.22}$ ${}^{U}oper^{-1.27}$	${}^{SHGC}all^{-0.25}$ ${}^{SHGC}north-^{0.61}$	${}^{U}fixed^{-1.22}$ ${}^{U}oper^{-1.27}$	${}^{SHGC}all^{-0.25}$ ${}^{SHGC}north^{-0.61}$	${}^{U}oper^{-1.27}$ ${}^{U}fixed^{-1.22}$	${}^{SHGC}all^{-NR}$ ${}^{SHGC}north^{NR}$
20.1-30.0%	${}^{U}fixed^{-1.22}$ ${}^{U}oper^{-1.27}$	${}^{SHGC}all^{-0.25}$ ${}^{SHGC}north^{-0.61}$	${}^{U}fixed^{-1.22}$ ${}^{U}oper^{-1.27}$	${}^{SHGC}all^{-0.25}$ ${}^{SHGC}north^{-0.61}$	${}^{U}fixed^{-1.22}$ ${}^{U}oper^{-1.27}$	${}^{SHGC}all^{-NR}$ ${}^{SHGC}north^{NR}$
30.1-40.0%	${}^{U}fixed^{-1.22}$ ${}^{U}oper^{-1.27}$	${}^{SHGC}all^{-0.25}$ ${}^{SHGC}north^{-0.61}$	${}^{U}fixed^{-1.22}$ ${}^{U}oper^{-1.27}$	${}^{SHGC}all^{-0.25}$ ${}^{SHGC}north^{-0.61}$	${}^{U}fixed^{-1.22}$ ${}^{U}oper^{-1.27}$	${}^{SHGC}all^{-NR}$ ${}^{SHGC}north^{NR}$
40.1-50.0%	${}^{U}fixed^{-1.22}$ ${}^{U}oper^{-1.27}$	${}^{SHGC}all^{-0.17}$ ${}^{SHGC}north^{-0.44}$	${}^{U}fixed^{-1.22}$ ${}^{U}oper^{-1.27}$	${}^{SHGC}all^{-0.17}$ ${}^{SHGC}north^{-0.43}$	${}^{U}fixed^{-0.98}$ ${}^{U}oper^{-1.02}$	${}^{SHGC}all^{-NR}$ ${}^{SHGC}north^{NR}$
Skylight with Curb, Glass, % of Roof 0-2.0%	${}^{U}all^{-1.98}$	${}^{SHGC}all^{-0.36}$	${}^{U}all^{-1.98}$	${}^{SHGC}all^{-0.19}$	${}^{U}all^{-1.98}$	${}^{SHGC}all^{-NR}$
2.1-5.0%	${}^{U}all^{-1.98}$	${}^{SHGC}all^{-0.19}$	${}^{U}all^{-1.98}$	${}^{SHGC}all^{-0.19}$	${}^{U}all^{-1.98}$	${}^{SHGC}all^{-NR}$
Skylight with Curb, Plastic, % of Roof 0-2.0%	${}^{U}all^{-1.90}$	${}^{SHGC}all^{-0.39}$	${}^{U}all^{-1.90}$	${}^{SHGC}all^{-0.27}$	${}^{U}all^{-1.90}$	${}^{SHGC}all^{-NR}$
2.1-5.0%	${}^{U}all^{-1.90}$	${}^{SHGC}all^{-0.34}$	${}^{U}all^{-1.90}$	${}^{SHGC}all^{-0.27}$	${}^{U}all^{-1.90}$	${}^{SHGC}all^{-NR}$
Skylight without Curb, All, % of Roof 0-2.0%	${}^{U}all^{-1.36}$	${}^{SHGC}all^{-0.36}$	${}^{U}all^{-1.36}$	${}^{SHGC}all^{-0.19}$	${}^{U}all^{-1.36}$	${}^{SHGC}all^{-NR}$
2.1-5.0%	${}^{U}all^{-1.36}$	${}^{SHGC}all^{-0.19}$	${}^{U}all^{-1.36}$	${}^{SHGC}all^{-0.19}$	${}^{U}all^{-1.36}$	${}^{SHGC}all^{-NR}$

*The following definitions apply: ci = continuous insulation (see Section 3.2), NR = no (insulation) requirement.

[a] Exception to A3.1.3.1 applies.

[b] Alternate to fenestration: Insulated low E glass having a SHGC of .35 will be acceptable in lieu of the table values for up to 40% glazing, provided the U Factor does not exceed 0.70. In the absence of a manufacturer's rated U Factor for insulated low E glass, use 0.70 as a default. For up to 50% glazing, insulated low E glass having a SHGC of 0.28 and a U factor of 0.70 is acceptable.

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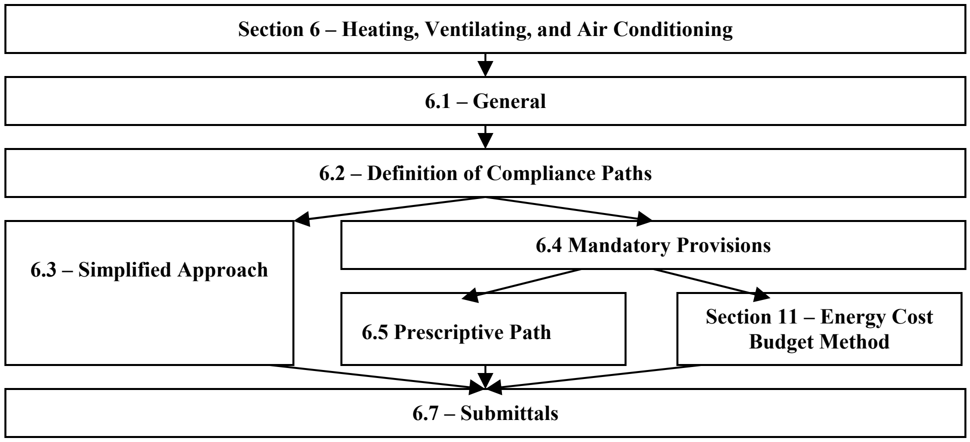
6. HEATING, VENTILATING, AND AIR CONDITIONING



6.1 General

6.1.1 Scope

6.1.1.1 New Buildings: Mechanical equipment and systems serving the heating, cooling, or ventilating needs of new buildings shall comply with the requirements of this section as described in 6.2.

6.1.1.2 Additions to Existing Buildings: Mechanical equipment and systems serving the heating, cooling, or ventilating needs of *additions* to *existing buildings* shall comply with the requirements of this section as described in 6.2.

Exception to 6.1.1.2: When HVAC to an *addition* is provided by existing HVAC *systems* and equipment, such existing *systems* and *equipment* shall not be required to comply with this code. However, any new *systems* or *equipment* installed must comply with specific requirements applicable to those *systems* and *equipment*.

6.1.1.3 Alterations to Heating, Ventilating, and Air-Conditioning in Existing Building.

6.1.1.3.1 New HVAC equipment as a direct replacement of existing HVAC equipment shall comply with the specific minimum *efficiency* requirements in this code applicable to that equipment.

6.1.1.3.2 New cooling systems installed to serve previously uncooled spaces shall comply with this section as described in 6.2.

6.1.1.3.3 Reserved.

6.1.1.3.4 New and replacement ductwork shall comply with 6.4.4.1 and 6.4.4.2.

6.1.1.3.5 New and replacement piping shall comply with 6.4.4.1.

Exceptions to 6.1.1.3: Compliance shall not be required:

(a) for *equipment* that is being modified or repaired but not replaced, provided that such modifications and/ or repairs will not result in an increase in the annual energy consumption of the equipment using the same energy type, or

(b) for a refrigerant change of existing *equipment*, or

(c) for the relocation of existing *equipment*, or

(d) for ducts and pipes where there is insufficient space or access to meet these requirements.

6.2 Compliance Path(s)

6.2.1 Compliance with Section 6 shall be achieved by meeting all requirements for 6.1, General; 6.7, Submittals, 6.8, Minimum Equipment Efficiency; and either

(a) 6.3, Simplified Approach Option for HVAC Systems; or

(b) 6.4, Mandatory Provisions; and 6.5, Prescriptive Path.

6.2.2 Projects using the Energy Cost Budget Method (Section 11 of this code), must comply with 6.4, the mandatory provisions of this section, as a portion of that compliance path.

6.3 Simplified Approach Option for HVAC Systems

6.3.1 Scope: The simplified approach is an optional path for compliance when the following conditions are met:

(a) building is two stories or less in height,

(b) *gross floor area* is less than 25,000 square feet, and

(c) each HVAC *system* in the building complies with the requirements listed in 6.3.2

6.3.2 Criteria: HVAC *system* must meet ALL of the following criteria:

(a) The *system* serves a single *HVAC zone*.

(b) Cooling (if any) shall be provided by a unitary packaged or split-system air conditioner that is either air-cooled or evaporatively cooled with *efficiency* meeting the requirements shown in Table 6.8.1A (air conditioners), Table 6.8.1B (heat pumps), or Table 6.8.1D (packaged terminal and room air conditioners and heat pumps) for the applicable equipment category.

(c) Air economizers (if any) shall be provided with either barometric or powered relief dampers sized to prevent overpressurization of the building. *Outdoor air* dampers for economizer use shall comply with 6.4.3.4.4.

(d) Heating (if any) shall be provided by a unitary packaged or split-system heat pump that meets the applicable *efficiency* requirements shown in Table 6.8.1B (heat pumps) or Table 6.8.1D (packaged terminal and room air conditioners and heat pumps), a fuel-fired furnace that meets the applicable *efficiency* requirements shown in Table 6.8.1E (furnaces, duct furnaces, and unit heaters), an electric resistance heater, or a baseboard system connected to a boiler that meets the applicable *efficiency* requirements shown in Table 6.8.1F (boilers).

(e) The *outdoor air* quantity supplied by the system shall be less than or equal to 3000 cfm and less than 30% of the supply air quantity at minimum *outdoor air* design conditions unless an energy recovery ventilation system is provided in accordance with the requirements in 6.5.6.

(f) The *system* shall be controlled by a manual changeover or capable of retaining programming and time setting during dual setpoint thermostat.

(g) If a heat pump equipped with auxiliary internal electric resistance heaters is installed, controls shall be provided that prevent supplemental heater operation when the heating load can be met by the heat pump alone during both steady-state operation and setback recovery. Supplemental heater operation is permitted during outdoor coil defrost cycles. Two means of meeting this requirement are (1) a digital or electronic thermostat designed for heat pump use that energizes auxiliary heat only when the heat pump has insufficient capacity to maintain setpoint or to warm up the space at a sufficient rate or (2) a multi-stage space thermostat and an outdoor air thermostat wired to energize auxiliary heat only on the last stage or the space thermostat and when outside air temperature is less than 40°F. Heat pumps whose minimum efficiency is regulated by NAECA and whose HSPF rating both meets the requirements shown in Table 6.8.1B and includes all usage of internal electric resistance heating are exempted from the control requirements of this part (6.3.2g).

(h) *Systems* serving spaces other than hotel/motel guest rooms, and other than those requiring continuous operation, which have both a cooling or heating capacity greater than 15,000 Btu/h and a supply fan motor power greater than ¾ hp, shall be provided with a time clock that (1) can start and stop the system under different schedules for seven different day-types per week, (2) is capable of retaining programming and time setting during a loss of power for a period of at least 10 hours, (3) includes an accessible manual override that allows temporary operation of the system for up to two hours, (4) is capable of temperature setback down to 55°F during off hours, and (5) is capable of temperature setup to 90°F during off hours.

(i) Except for piping within *manufacturer's* units, HVAC piping shall be insulated in accordance with Table 6.8.3. Insulation exposed to weather shall be suitable for outdoor service, e.g., protected by aluminum, sheet metal, painted canvas, or plastic cover. Cellular foam insulation shall be protected as above or painted with a coating that is water retardant and provides shielding from solar radiation.

(j) Ductwork and plenums shall be insulated in accordance with Table 6.4.4.1.1 and shall be sealed in accordance with 6.4.4.2.1.

(k) Construction documents shall require a ducted *system* to be air balanced in accordance with one of the following standards:

1. 6.7.2.3.1 NEBB Procedural Standards – 1999 Procedural standards for building systems commissioning
2. 6.7.2.3.1 AABC 2002 Associated Air Balance Council Test and Balance procedures
3. 6.7.2.3.1 ASHRAE Standard 111 – 1988 Practices for Measurement, Testing, Adjusting and Balancing of Building Heating, Ventilation, Air-Conditioning and Refrigeration.

(l) Where separate heating and cooling equipment serves the same temperature zone, thermostats shall be interlocked to prevent simultaneous heating and cooling except for humidity control.

(m) Exhausts with a design capacity of over 300 cfm on *systems*, that do not operate continuously shall be equipped with gravity or motorized dampers that will automatically shut when the *systems* are not in use.

(n) *Systems* with a design supply air capacity greater than 10,000 cfm shall have *optimum start controls*.

(o) Outside air intakes shall have motorized dampers with leakage rate not to exceed 0.3 cfm at 1.0 in. w.g. cfm per ft^2 of damper area. Outside air dampers and exhaust fans shall be interlocked to close the damper and turn off the fan when the supply air system is de-energized.

6.4 Mandatory Provisions

6.4.1 Equipment Efficiencies, Verification, and Labeling Requirements

6.4.1.1 Minimum Equipment Efficiencies – Listed Equipment – Standard Rating and Operating Conditions. Equipment shown in Tables 6.8.1A through 6.8.1G shall have a minimum performance at the specified rating conditions when tested in accordance with the specified test procedure. Where multiple rating conditions or performance requirements are provided, the equipment shall satisfy all stated requirements, unless otherwise exempted by footnotes in the table. Equipment covered under the Federal Energy Policy Act of 1992 (EPACT) shall have no minimum *efficiency* requirements for operation at minimum capacity or other than standard rating conditions. Equipment used to provide water heating functions as part of a combination system shall satisfy all stated requirements for the appropriate space heating or cooling category.

Tables are as follows:

(a) Table 6.8.1A - Air Conditioners and Condensing Units

(b) Table 6.8.1B - Heat Pumps

(c) Table 6.8.1C - Water Chilling Packages (see 6.4.1.2 for water-cooled centrifugal water-chilling packages that are designed to operate at nonstandard conditions)

(d) Table 6.8.1D - Packaged Terminal and Room Air Conditioners and Heat Pumps

(e) Table 6.8.1E - Furnaces, Duct Furnaces, and Unit Heaters

(f) Table 6.8.1F – Boilers

(g) Table 6.8.1G - Heat Rejection Equipment

All furnaces with input ratings of ≥225,000 Btu/h, including electric furnaces, that are not located within the conditioned space shall have jacket losses not exceeding 0.75% of the input rating.

6.4.1.2 Minimum Equipment Efficiencies – Listed Equipment – Nonstandard Conditions: Water-cooled centrifugal water-chilling packages that are not designed for operation at ARI Standard 550/590 test conditions (and thus cannot be tested to meet the requirements of Table 6.8.1(C) of 44°F leaving chilled water temperature and 87°F entering condenser water temperature with 3 gpm/ton condenser water flow shall have a minimum full-load COP and a minimum NPLV rating as shown in tables referenced below.

(a) Centrifugal chillers <150 tons shall meet the minimum full-load COP and IPLV/NPLV in Table 6.8.1H.

(b) Centrifugal chillers ≥150 tons and <300 tons shall meet the minimum full-load COP and IPLV/NPLV in Table 6.8.1I.

(c) Centrifugal chillers ≥300 tons shall meet the minimum full-load COP and IPLV/NPLV in Table 6.8.1J. The table values are only applicable over the following full-load design ranges:

Leaving Chiller Water Temperature: 40°F to 48°F

Entering Condenser Water Temperature: 75°F to 87° F

Condensing Water Temperature Rise: 5°F to 15°F

Chillers designed to operate outside of these ranges or applications utilizing fluids or solutions with secondary coolants (e.g., glycol solutions or brines) with a freeze point of 27°F or less for freeze protection are not covered by this code. All chillers shall meet the minimum ARI efficiency performance requirements of Tables 6.8.1H, 6.8.1I, and 6.8.1J, regardless of the operating conditions.

6.4.1.3 Equipment Not Listed. Equipment not listed in the tables referenced in 6.4.1.1 and 6.4.1.2 may be used in the Energy Cost Budget Method and Appendix G.

6.4.1.4 Verification of Equipment Efficiencies. Equipment *efficiency* information supplied by *manufacturers* shall be verified as follows:

(a) Equipment covered under the Federal Energy Policy Act of 1992 (EPACT) shall comply with U.S. Department of Energy certification requirements.

(b) If a certification program exists for a covered product, and it includes provisions for verification and challenge of equipment *efficiency* ratings, then the product shall be listed in the certification program, or,

(c) if a certification program exists for a covered product, and it includes provisions for verification and challenge of equipment *efficiency* ratings, but the product is not listed in the existing certification program, the ratings shall be verified by an independent laboratory test report, or

(d) if no certification program exists for a covered product, the equipment *efficiency* ratings shall be supported by data furnished by the *manufacturer*, or

(e) where components such as indoor or outdoor coils from different *manufacturers* are used, the system designer shall specify component efficiencies whose combined *efficiency* meets the minimum equipment *efficiency* requirements in 6.4.1.

(f) Products covered in Table 6.8.1G shall have efficiency ratings supported by data furnished by the manufacturer.

6.4.1.5 Labeling

6.4.1.5.1 Mechanical Equipment. Mechanical equipment that is not covered by the U.S. National Appliance Energy Conservation Act (NAECA) of 1987 shall carry a permanent label installed by the *manufacturer* stating that the equipment complies with the requirements of ASHRAE/ IESNA Standard 90.1.

6.4.1.5.2 Packaged Terminal Air Conditioners. Packaged terminal air conditioners and heat pumps with sleeve sizes less than 16 in. high and 42 in. wide shall be factory labeled as follows: *Manufactured for replacement applications only: not to be installed in new construction projects.*

6.4.2 Load Calculations. Heating and cooling system design loads for the purpose of sizing systems and equipment shall be determined in accordance with generally accepted engineering standards and methods (for example, *ASHRAE Handbook—Fundamentals*).

6.4.3 Controls

6.4.3.1 Zone Thermostatic Controls

6.4.3.1.1 General. The supply of heating and cooling energy to each *zone* shall be individually controlled by thermostatic controls responding to temperature within the *zone*. For the purposes of 6.4.3.1, a dwelling unit shall be permitted to be considered a single *zone*.

Exceptions to 6.4.3.1.1: Independent perimeter systems that are designed to offset only *building envelope* loads shall be permitted to serve one or more zones also served by an interior system provided:

(a) the perimeter system includes at least one thermostatic control zone for each building exposure having exterior walls facing only one *orientation* for 50 contiguous feet or more, and

(b) the perimeter system heating and cooling supply is controlled by a thermostatic control(s) located within the zones(s) served by the system.

Exterior walls are considered to have different *orientations* if the directions they face differ by more than 45 degrees.

6.4.3.1.2 Dead Band. Where used to control both heating and cooling, zone thermostatic controls shall be capable of providing a temperature range or dead band of at least 5°F within which the supply of heating and cooling energy to the zone is shut off or reduced to a minimum.

Exceptions to 6.4.3.1.2:

(a) Thermostats that require manual changeover between heating and cooling modes.

(b) Special occupancy or special applications where wide temperature ranges are not acceptable (such as retirement homes, process applications, data processing, museums, some areas of hospitals) and are approved by the *authority having jurisdiction*.

6.4.3.2 Setpoint Overlap Restriction. Where heating and cooling to a zone are controlled by separate zone thermostatic controls located within the zone, means (such as limit switches, mechanical stops, or, for DDC systems, software programming) shall be provided to prevent the heating set-point from exceeding the cooling setpoint minus any applicable proportional band.

6.4.3.3 Off-Hour Controls. HVAC systems shall have the off-hour controls required by Sections 6.4.3.3.1 through 6.4.3.3.4.

Exceptions to 6.4.3.3:

(a) *HVAC systems* serving hotel/motel guest rooms.

(b) *HVAC systems* intended to operate continuously.

(c) *HVAC systems* having a design heating capacity and cooling capacity less than 15,000 Btu/h that are equipped with readily accessible manual on/off controls.

6.4.3.3.1 Automatic Shutdown. *HVAC systems* shall be equipped with at least one of the following:

(a) Controls that can start and stop the system under different time schedules for seven different day-types per week, are capable of retaining programming and time setting during loss of power for a period of at least 10 hours, and include an accessible manual override, or equivalent function, that allows temporary operation of the system for up to two hours.

(b) An *occupant sensor* that is capable of shutting the system off when no occupant is sensed for a period of up to 30 minutes.

(c) A manually operated timer capable of being adjusted to operate the system for up to two hours.

(d) An interlock to a security system that shuts the system off when the security system is activated.

Exception to 6.4.3.3.1: Residential occupancies may use controls that can start and stop the system under two different time schedules per week.

6.4.3.3.2 Setback Controls. Heating systems shall be equipped with controls that have the capability to automatically restart and temporarily operate the system as required to maintain *zone* temperatures above a heating setpoint adjustable down to 55°F or lower. Cooling systems shall be equipped with controls that have the capability to automatically restart and temporarily operate the system as required to maintain *zone* temperatures below a cooling setpoint adjustable up to 85°F or higher or to prevent high space humidity levels.

Exception to 6.4.3.3.2: Radiant floor and ceiling heating *systems*.

6.4.3.3.3 Optimum Start Controls. Individual heating and cooling air distribution systems with a total design supply air capacity exceeding 10,000 cfm, served by one or more supply fans, shall have *optimum start controls*. The control algorithm shall, as a minimum, be a function of the difference between space temperature and occupied setpoint and the amount of time prior to scheduled occupancy.

6.4.3.3.4 Zone Isolation. *HVAC systems* serving *zones* that are intended to operate or be occupied nonsimultaneously shall be divided into isolation areas. Zones may be grouped into a single isolation area provided it does not exceed 25,000 ft^2 of conditioned floor area nor include more than one floor. Each isolation area shall be equipped with *isolation devices* capable of automatically shutting off the supply of conditioned air and *outdoor air* to and exhaust air from the area. Each isolation area shall be controlled independently by a device meeting the requirements of 6.4.3.3.1 (Automatic Shutdown). For central systems and plants, controls and devices shall be provided to allow stable system and equipment operation for any length of time while serving only the smallest isolation area served by the system or plant.

Exceptions to 6.4.3.3.4: Isolation devices and controls are not required for the following:

(a) Exhaust airflow from a single isolation *zone* of less than 10% of the design airflow of the exhaust system to which it connects.

(b) *Zones* intended to operate continuously or intended to be inoperative only when all other *zones* are inoperative.

6.4.3.4 Ventilation System Controls.

6.4.3.4.1 Stair and Shaft Vents. Stair and elevator shaft vents shall be equipped with motorized dampers that are capable of being automatically closed during normal building operation and are interlocked to open as required by fire and smoke detection systems.

6.4.3.4.2 Gravity Hoods, Vents, and Ventilators. All *outdoor air* supply and exhaust hoods, vents, and ventilators shall be equipped with motorized dampers that will automatically shut when the spaces served are not in use.

Exceptions to 6.4.3.4.1 and 6.4.3.4.2:

(a) Ventilation systems serving *unconditioned spaces*.

(b) In systems where dampers are prohibited by the *Mechanical Code*.

6.4.3.4.3 Shutoff Damper Controls. Both *outdoor air* supply and exhaust systems shall be equipped with motorized dampers that will automatically shut when the systems or spaces served are not in use. Ventilation *outdoor air* dampers shall be capable of automatically shutting off during preoccupancy building warm-up, cool down, and *setback*, except when *ventilation* reduces energy costs (e.g., night purge) or when ventilation must be supplied to meet code requirements.

Exceptions to 6.4.3.4.3:

(a) Gravity (nonmotorized) dampers are acceptable in exhaust systems in buildings less than 3 stories in height.

(b) Gravity (nonmotorized) dampers are acceptable in systems with a design *outdoor air* intake or exhaust capacity of 300 cfm or less.

(c) In systems where dampers are prohibited by the *Mechanical Code*.

6.4.3.4.4 Dampers. Where *outdoor air* supply and exhaust air dampers are required by Section 6.4.3.4, they shall have a maximum leakage rate of 0.3 cfm per square foot.

6.4.3.4.5 Ventilation Fan Controls. Fans with motors greater than ¾ hp (0.5 kW) shall have automatic controls complying with Section 6.4.3.3.1 that are capable of shutting off fans when not required.

Exception to 6.4.3.4.5: *HVAC systems* intended to operate continuously.

6.4.3.5 Heat Pump Auxiliary Heat Control. Heat pumps equipped with internal electric resistance heaters shall have controls that prevent supplemental heater operation when the heating load can be met by the heat pump alone during both steady-state operation and setback recovery. Supplemental heater operation is permitted during outdoor coil defrost cycles.

Exception to 6.4.3.5: Heat pumps whose minimum *efficiency* is regulated by NAECA and whose HSPF rating both meets the requirements shown in Table 6.8.1B and includes all usage of internal electric resistance heating.

6.4.3.6 Humidifier Preheat. Humidifiers with preheating jackets mounted in the airstream shall be provided with an automatic valve to shut off preheat when humidification is not required.

6.4.3.7 Humidification and Dehumidification. Where a *zone* is served by a system or systems with both humidification and dehumidification capability, means (such as limit switches, mechanical stops, or, for DDC systems, software programming) shall be provided capable of preventing simultaneous operation of humidification and dehumidification equipment.

Exceptions to 6.4.3.7:

(a) Zones served by desiccant systems, used with direct evaporative cooling in series.

(b) Systems serving zones where specific humidity levels are required, such as computer rooms, museums, and hospitals, and approved by the *authority having jurisdiction*.

6.4.3.8 Freeze Protection and Snow/Ice Melting Systems. Freeze protection systems, such as heat tracing of outdoor piping and heat exchangers, including self-regulating heat tracing, shall include automatic controls capable of shutting off the systems when *outdoor air* temperatures are above 40°F or when the conditions of the protected fluid will prevent freezing. Snow- and ice-melting systems shall include automatic controls capable of shutting off the systems when the pavement temperature is above 50°F and no precipitation is falling and an automatic or manual control that will allow shutoff when the outdoor temperature is above 40°F so that the potential for snow or ice accumulation is negligible.

6.4.3.9 Ventilation Controls for High-Occupancy Areas. Systems with design *outdoor air* capacities greater than 3000 cfm serving areas having an average design occupancy density exceeding 100 people per 1000 ft^2 shall include means to automatically reduce *outdoor air* intake below design rates when spaces are partially occupied. Ventilation controls shall be in compliance with the *Mechanical Code*.

Exception to 6.4.3.9: Systems with energy recovery complying with 6.5.6.1.

6.4.4 HVAC System Construction and Insulation

6.4.4.1 Insulation

6.4.4.1.1 General. Insulation required by this section shall be installed in accordance with Table 6.4.4.1.1. These requirements do not apply to HVAC equipment. Insulation shall be protected from damage, including that due to sunlight, moisture, equipment maintenance and wind, but not limited to the following:

(a) Insulation exposed to weather shall be suitable for outdoor service, e.g., protected by aluminum, sheet metal, painted canvas, or plastic cover. Cellular foam insulation shall be protected as above or painted with a coating that is water retardant and provides shielding from solar radiation that can cause degradation of the material.

(b) Insulation covering chilled water piping, refrigerant suction piping, or cooling ducts located outside the conditioned space shall include a vapor retardant located outside the insulation (unless the insulation is inherently vapor retardant), all penetrations and joints of which shall be sealed.

TABLE 6.4.4.1.1 Insulation of Ducts

Duct Location	Insulation Types Mechanically Cooled and Outside Air	Insulation Types Heating Only
1. On roof or exterior of building	R-8, V, W	R-8,W
2. Attics, garages, inside walls, floor-ceiling spaces and crawl spaces (located inside the building envelope)	R-6,V	R-6
3. Attics, garages, outside walls, and crawl spaces (located outside the building envelope)	R-8,V	R-8

a. When the temperature difference between the interior and the exterior of the duct does not exceed 15º F (8 º C) duct insulation is not required.
b. Where ducts are used for both heating and cooling, the insulation requirements shall comply with the most restrictive condition.

NOTES:
V. Vapor retarders: Material with a perm rating not exceeding 0.5 perm (29 ng/Pa●s●m^2). Vapor retarders shall be installed on cooling supply ducts in spaces vented to the outside in geographic areas where the summer dew point temperature exceeds 60°F (16°C) at the 2 ½ percent summer design dry-bulb with mean coincident wet-bulb temperature. All joints to be sealed.

W. Approved weatherproof barrier.

6.4.4.1.2 Duct and Plenum Insulation. All supply and return ducts and plenums installed as part of an HVAC air distribution system shall be thermally insulated in accordance with the Table 6.4.4.1.1.

Exception to 6.4.4.1.2: Factory-installed plenums, casings, or ductwork furnished as a part of HVAC equipment tested and rated in accordance with 6.4.1.

6.4.4.1.3 Piping Insulation. Piping shall be thermally insulated in accordance with Table 6.8.3.

Exceptions to 6.4.4.1.3:

(a) Factory-installed piping within HVAC equipment tested and rated in accordance with 6.4.1.

(b) Piping that conveys fluids having a design operating temperature range between 60°F and 105°F, inclusive.

(c) Piping that conveys fluids that have not been heated or cooled through the use of nonrenewable energy where heat gain or heat loss will not increase energy usage.

(d) Hot water piping between the shutoff valve and the coil, not exceeding 4 ft in length, when located in *conditioned spaces*.

(e) Pipe unions in heating systems (steam, steam condensate, and hot water).

6.4.4.2 Ducts and Plenum Leakage

6.4.4.2.1 Duct Sealing. Ductwork and plenums shall be sealed in accordance with the Mechanical Code and SMACNA Method A.

6.4.4.2.2 Duct Leakage Tests. Ductwork that is designed to operate at static pressures in excess of 3 in. w.c. shall be leak tested according to industry-accepted test procedures (see Appendix E). Representative sections totaling no less than 25% of the total installed duct area for the designated pressure class shall be tested. Duct systems with pressure ratings in excess of 3 in. w.c. shall be identified on the drawings. The maximum permitted duct leakage shall be no more than 1% of the total airflow in the section tested.

6.4.5 Completion Requirements. Completion Requirements are as described in Section 6.7.2.

6.5 Prescriptive Path

6.5.1 Reserved.

6.5.1.1 Air Economizers (When used.)

6.5.1.1.1 Design Capacity. Air economizer systems shall be capable of modulating *outdoor air* and return air dampers to provide up to 100% of the design supply air quantity as *outdoor air* for cooling.

6.5.1.1.2 Control Signal. Economizer dampers shall be capable of being sequenced with the mechanical cooling equipment and shall not be controlled by only mixed air temperature.

Exception to 6.5.1.1.2: The use of mixed air temperature limit control shall be permitted for systems controlled from space temperature (such as single-zone systems).

6.5.1.1.3 High-Limit Shutoff. All air economizers shall be capable of automatically reducing *outdoor air* intake to the design minimum *outdoor air* quantity when *outdoor air* intake will no longer reduce cooling energy usage. High-limit shutoff control types for specific climates shall be chosen from Table 6.5.1.1.3A. High-limit shutoff control settings for these control types shall be those listed in Table 6.5.1.1.3B.

TABLE 6.5.1.1.3A High-Limit Shutoff Control Options for Air Economizers

Allowed Control Types	Prohibited Control Types
Fixed Dry Bulb Fixed Enthalpy Electronic Enthalpy[a] Differential Enthalpy Dew-Point and Dry-Bulb Temperature	Differential Dry Bulb

[a] Electronic enthalpy controllers are devices that use a combination of humidity and dry-bulb temperature in their switching algorithm.

TABLE 6.5.1.1.3B High-Limit Shutoff Control Settings for Air Economizers

Device Type	Required High Limit (Economizer Off When):	
	Equation	Description
Fixed Dry Bulb	$T_{OA} > 65°$	*Outdoor air* temperature exceeds 65°F
Fixed Enthalpy	$h_{OA} > 28$ Btu/lb[a]	*Outdoor air* enthalpy exceeds 28 Btu/lb of dry air[a]
Electronic Enthalpy	(T_{OA}, RH_{OA})	*Outdoor air* temperature/RH exceeds the "A" set point curve[a]
Differential Enthalpy	$h_{OA} > h_{RA}$	*Outdoor air* enthalpy exceeds return air enthalpy
Dew Point and Dry-Bulb Temperature	DP_{oa}>55°F or T_{oa}>75°F	*Outdoor air* dry bulb exceeds 75°F or outside dew point exceeds 55°F (65 gr/lb)

[a] Set point "A" corresponds to a curve on the psychometric chart that goes through a point at approximately 75°F and 40% relative humidity and is nearly parallel to dry-bulb lines at low humidity levels and nearly parallel to enthalpy lines at high humidity levels.

6.5.1.1.4 Dampers. Both return air and *outdoor air* dampers shall meet the requirements of 6.4.3.3.4.

6.5.1.1.5 Relief of Excess *Outdoor Air*. Systems shall provide a means to relieve excess *outdoor air* during air economizer operation to prevent over pressurizing the building. The relief air outlet shall be located to avoid recirculation into the building.

6.5.1.2 Water Economizers

6.5.1.2.1 Design Capacity. Water economizer systems shall be capable of cooling supply air by indirect evaporation and providing up to 100% of the expected system cooling load at air temperatures of 50°F dry bulb/ 45°F wet bulb and below.

Exception to 6.5.1.2.1: Systems in which a water economizer is used and where dehumidification requirements cannot be met using *outdoor air* temperatures of 50°F dry bulb/45°F wet bulb must satisfy 100% of the expected system cooling load at 45°F dry bulb/40°F wet bulb.

6.5.1.2.2 Maximum Pressure Drop. Precooling coils and water-to-water heat exchangers used as part of a water economizer system shall either have a water-side pressure drop of less than 15 ft of water or a secondary loop shall be created so that the coil or heat exchanger pressure drop is not seen by the circulating pumps when the system is in the normal cooling (noneconomizer) mode.

6.5.1.3 Integrated Economizer Control. Economizer systems shall be integrated with the mechanical cooling system and be capable of providing partial cooling even when additional mechanical cooling is required to meet the remainder of the cooling load.

Exceptions to 6.5.1.3:

(a) Direct expansion systems that include controls that reduce the quantity of *outdoor air* required to prevent coil frosting at the lowest step of compressor unloading, provided this lowest step is no greater than 25% of the total system capacity.

(b) Individual direct expansion units that have a rated cooling capacity less than 65,000 Btu/h and use nonintegrated economizer controls that preclude simultaneous operation of the economizer and mechanical cooling.

(c) Systems in climate zones 1, 2, 3a, 4a, 5a, 5b, 6, 7, 8.

6.5.1.4 Economizer Heating System Impact. HVAC system design and economizer controls shall be such that economizer operation does not increase the building heating energy use during normal operation.

Exception to 6.5.1.4: Economizers on VAV systems that cause zone level heating to increase due to a reduction in supply air temperature.

6.5.2 Simultaneous Heating and Cooling Limitation

6.5.2.1 Zone Controls. *Zone* thermostatic controls shall be capable of operating in sequence the supply of heating and cooling energy to the *zone*. Such controls shall prevent:

1. *reheating*,
2. *recooling*,
3. mixing or simultaneously supplying air that has been previously mechanically heated and air that has been previously cooled, either by mechanical cooling or by economizer systems, and
4. other simultaneous operation of heating and cooling systems to the same *zone*.

Exceptions to 6.5.2.1:

(a) *Zones* for which the volume of air that is reheated, recooled, or mixed is no greater than the larger of the following:

1. the volume of *outdoor air* required to meet the ventilation requirements of Section 6.1.3 of ASHRAE Standard 62 for the *zone*,
2. 0.5 cmf/ft^2 of the *zone* conditioned floor area,
3. 50% of the *zone* design peak supply rate,
4. 300 cfm—this exception is for zones whose peak flow rate totals no more than 10% of the total fan system flow rate,
5. any higher rate that can be demonstrated, to the satisfaction of the *authority having jurisdiction*, to reduce overall system annual energy usage by offsetting reheat/recool energy losses through a reduction in *outdoor air* intake in accordance with the multiple space requirements defined in ASHRAE Standard 62.

(b) *Zones* where special pressurization relationships, cross-contamination requirements, or code-required minimum circulation rates are such that variable air volume systems are impractical.

(c) *Zones* where at least 75% of the energy for reheating for providing warm air in mixing systems is provided from a *site-recovered* (including condenser heat) or *site- solar energy source*.

6.5.2.2 Hydronic System Controls. The heating of fluids in hydronic systems that have been previously mechanically cooled and the cooling of fluids that have been previously mechanically heated shall be limited in accordance with 6.5.2.2.1 through 6.5.2.2.3.

6.5.2.2.1 Three-Pipe System. Hydronic systems that use a common return system for both hot water and chilled water shall not be used.

6.5.2.2.2 Two-Pipe Changeover System. Systems that use a common distribution system to supply both heated and chilled water shall not be used.

6.5.2.2.3 Hydronic (Water Loop) Heat Pump Systems. Hydronic heat pumps connected to a common heat pump water loop with central devices for heat rejection (e.g., cooling tower) and heat addition (e.g., boiler) shall have the following:

(a) Controls that are capable of providing a heat pump water supply temperature deadband of at least 20°F between initiation of heat rejection and heat addition by the central devices (e.g., tower and boiler).

(b) If a closed-circuit tower (fluid cooler) is used, either an automatic valve shall be installed to bypass all but a minimal flow of water around the tower (for freeze protection) or low-leakage positive closure dampers shall be provided. If an open-circuit tower is used directly in the heat pump loop, an automatic valve shall be installed to bypass all heat pump water flow around the tower. If an open-circuit tower is used in conjunction with a separate heat exchanger to isolate the tower from the heat pump loop, then heat loss shall be controlled by shutting down the circulation pump on the cooling tower loop.

Exception to 6.5.2.2.3: Where a system loop temperature optimization controller is used to determine the most efficient operating temperature based on real-time conditions of demand and capacity, dead bands of less than 20°F shall be allowed.

6.5.2.3 Dehumidification. Where humidistatic controls are provided, such controls shall prevent reheating, mixing of hot and cold airstreams, or other means of simultaneous heating and cooling of the same airstream.

Exception to 6.5.2.3: For the purposes of humidity control.

6.5.3 Air System Design and Control. HVAC systems having a total *fan system power* exceeding 5 hp shall meet the provisions of 6.5.3.1 through 6.5.3.2 unless otherwise noted.

6.5.3.1 Reserved.

6.5.3.2 Variable Air Volume (VAV) Fan Control (Including Systems Using Series Fan Power Boxes).

6.5.3.2.1 Part-Load Fan Power Limitation. Individual VAV fans with motors 5 hp and larger shall meet one of the following:

(a) The fan shall be driven by a mechanical or electrical variable-speed drive.

(b) The fan shall be a vane-axial fan with variable-pitch blades.

(c) The fan shall have other controls and devices that will result in fan motor demand of no more than 30% of design wattage at 50% of design air volume when static pressure setpoint equals one-third of the total design static pressure, based on *manufacturer's* certified fan data.

6.5.3.2.2 VAV Fans with Motor Requirement of 1 hp and Less. Individual VAV fans with motor requirements of 1 hp and less fan powered terminal units shall be driven by electronically commutated motors (ECM).

6.5.4 Hydronic System Design and Control. HVAC hydronic systems having a total *pump system power* exceeding 10 hp shall meet provisions of 6.5.4.1 through 6.5.4.4.

6.5.4.1 Hydronic Variable Flow Systems. HVAC pumping systems that include control valves designed to modulate or step open and close as a function of load shall be designed for variable fluid flow and shall be capable of reducing pump flow rates to 50% or less of the design flow rate. Individual pumps serving variable flow systems having a pump head exceeding 100 ft and motor exceeding 50 hp shall have controls and/or devices (such as variable speed control) that will result in pump motor demand of no more than 30% of design wattage at 50% of design water flow. The controls or devices shall be controlled as a function of desired flow or to maintain a minimum required differential pressure. Differential pressure shall be measured at or near the most remote heat exchanger or the heat exchanger requiring the greatest differential pressure.

Exceptions to 6.5.4.1:

(a) Systems where the minimum flow is less than the minimum flow required by the equipment *manufacturer* for the proper operation of equipment served by the system, such as chillers and boilers.

(b) Systems that include no more than three control valves.

6.5.4.2 Pump Isolation. When a chilled water plant includes more than one chiller, provisions shall be made so that the flow in the chiller plant can be automatically reduced, correspondingly, when a chiller is shut down. Chillers referred to in this section, piped in series for the purpose of increased temperature differential, shall be considered as one chiller.

When a boiler plant includes more than one boiler, provisions shall be made so that the flow in the boiler plant can be automatically reduced, correspondingly, when a boiler is shut down.

6.5.4.3 Chilled and Hot Water Temperature Reset Controls. Chilled and hot water systems with a design capacity exceeding 300,000 Btu/h supplying chilled or heated water to comfort conditioning systems shall include controls that have the capability to automatically reset supply water temperatures by representative building loads (including return water temperature) or by *outdoor* air enthalpy.

Exceptions to 6.5.4.3:

(a) Where the supply temperature reset controls cannot be implemented without causing improper operation of heating, cooling, humidifying, or dehumidifying systems.

(b) Hydronic systems, such as those required by 6.5.4.1 that use variable flow to reduce pumping energy.

6.5.4.4 Hydronic (Water Loop) Heat Pump Systems. Each hydronic heat pump shall have a two-position automatic valve interlocked to shut off water flow when the compressor is off.

6.5.5 Reserved

6.5.6 Energy Recovery

6.5.6.1 Exhaust Air Energy Recovery. Individual fan systems that have both a design supply air capacity of 5000 cfm or greater and have a minimum *outdoor air supply* of 70% or greater of the design supply air quantity shall have an energy recovery system.

Exceptions to 6.5.6.1:

(a) Laboratory systems with fume hood systems having a total exhaust rate less than or equal to 15,000 cfm, or when greater than 15,000 cfm, that include at least one of the following features:

1. Variable air volume hood exhaust and room supply systems capable of reducing exhaust and makeup air volume to 50% or less of design values.
2. Direct makeup (auxiliary) air supply equal to at least 75% of the exhaust rate, heated no warmer than 2°F below room setpoint, cooled to no cooler than 3°F above room setpoint, no humidification added, and no simultaneous heating and cooling used for humidification control.
3. Heat recovery systems to precondition makeup air from fume hood exhaust in accordance with 6.5.6.1 (Exhaust Air Energy Recovery) without using any exception.

(b) Systems serving spaces that are not cooled and that are heated to less than 60°F.

(c) Systems exhausting toxic, flammable, paint, or corrosive fumes or dust.

(d) Commercial kitchen hoods used for collecting and removing grease vapors and smoke.

(e) Where more than 60% of the *outdoor air* heating energy is provided from site-recovered or site solar energy.

(f) Heating systems in climate zone 2.

(g) Where the largest exhaust source is less than 75% of the design *outdoor air* flow.

(h) Systems requiring dehumidification that employ energy recovery in series with the cooling coil.

6.5.7 Reserved.

6.5.8 Radiant Heating Systems

6.5.8.1 Heating Unenclosed Spaces. Radiant heating shall be used when heating is required for unenclosed spaces.

Exception to 6.5.8.1: Loading docks equipped with air curtains.

6.5.8.2 Heating Enclosed Spaces. Radiant heating systems that are used as primary or supplemental enclosed space heating must be in conformance with the governing provisions of the code, including, but not limited to, the following:

(a) Radiant hydronic ceiling or floor panels (used for heating or cooling).

(b) Combination or hybrid systems incorporating radiant heating (or cooling) panels.

(c) Radiant heating (or cooling) panels used in conjunction with other systems such as variable air volume or thermal storage systems.

6.5.9 Hot Gas Bypass Limitation. Cooling systems shall not use hot gas bypass or other evaporator pressure control systems unless the system is designed with multiple steps of unloading or continuous capacity modulation. The capacity of the hot gas bypass shall be limited as indicated in Table 6.5.9.

Exception to 6.5.9: Unitary packaged systems with cooling capacities not greater than 90,000 Btu/h.

TABLE 6.5.9 Hot Gas Bypass Limitation

Rated Capacity	Maximum Hot Gas Bypass Capacity (% of Total Capacity)
≤240,000 Btu/h	50%
>240,000 Btu/h	25%

6.6 Alternative Compliance Path: (Not Used)

6.7 Submittals

6.7.1 General. *Authority having jurisdiction* shall be permitted to require submittal of compliance documentation and supplemental information, in accord with Section 4.2.2 of this code.

6.7.2 Completion Requirements: The following requirements are mandatory provisions and are necessary for compliance with the code.

6.7.2.1 Drawings. Construction documents shall require that within 90 days after the date of system acceptance record drawings of the actual installation be provided to the building owner or the designated representative of the building owner. Record drawings shall include as a minimum the location and performance data on each piece of equipment, general configuration of duct and pipe distribution system including sizes, and the terminal air or water design flow rates.

6.7.2.2 Manuals. Construction documents shall require that an operating manual and a maintenance manual be provided to the building owner or the designated representative of the building owner within 90 days after the date of system acceptance. These manuals shall be in accordance with industry-accepted standards (see Appendix E) and shall include, at a minimum, the following:

(a) Submittal data stating equipment size and selected options for each piece of equipment requiring maintenance.

(b) Operation manuals and maintenance manuals for each piece of equipment requiring maintenance, except equipment not furnished as part of the project. Required routine maintenance actions shall be clearly identified.

(c) Names and addresses of at least one *service agency*.

(d) HVAC controls system maintenance and calibration information, including wiring diagrams, schematics, and control sequence descriptions. Desired or field-determined setpoints shall be permanently recorded on control drawings at control devices or, for digital control systems, in programming comments.

(e) A complete narrative of how each system is intended to operate, including suggested setpoints.

6.7.2.3 System Balancing

6.7.2.3.1 General. Construction documents shall require that all HVAC systems be balanced in accordance with generally accepted engineering standards (see Appendix E). Construction documents shall require that a written balance report be provided to the owner or the designated representative of the building owner for HVAC systems serving *zones* with a total conditioned area exceeding 5000 ft^2.

6.7.2.3.2 Air System Balancing. Air systems shall be balanced in a manner to first minimize throttling losses. Then, for fans with *fan system power* greater than 1 hp, fan speed shall be adjusted to meet design flow conditions.

6.7.2.3.3 Hydronic System Balancing. Hydronic systems shall be proportionately balanced in a manner to first minimize throttling losses; then the pump impeller shall be trimmed or pump speed shall be adjusted to meet design flow conditions.

Exceptions to 6.7.2.3.3: Impellers need not be trimmed nor pump speed adjusted:

(a) For pumps with pump motors of 10 hp or less.

(b) When throttling results in no greater than 5% of the nameplate horsepower draw, or 3 hp, whichever is greater, above that required if the impeller was trimmed.

6.7.2.4 Control Verification. HVAC control systems shall be tested to ensure that control elements are calibrated, adjusted, and in proper working condition.

6.7.2.5 System Commissioning. HVAC control systems shall be tested to ensure that control elements are calibrated, adjusted, and in proper working condition. For projects larger than 50,000 ft^2 conditioned area, except heated only warehouses and semiheated spaces, detailed instructions for commissioning HVAC systems (see Appendix E) shall be provided by the designer in plans and specifications.

6.8 Minimum Equipment Efficiency Tables

6.8.1 Minimum Efficiency Requirement Listed Equipment—Standard Rating and Operating Conditions

TABLE 6.8.1A Electronically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air Conditioners Air Cooled	< 65,000 Btu/h[c]	All	Split System	12.0 SEER	ARI 210/240
			Single Package	12.0 SEER	
Through-the-Wall, Air Cooled	≤ 30,000 Btu/h[c]	All	Split System	10.9 SEER 12.0 SEER (as of 1/23/2010)	
			Single Package	9.7 SEER 12.0 SEER (as of 1/23/2010)	
Small-Duct High-Velocity, Air Cooled	< 65,000 Btu/h[c]	All	Split System	10 SEER	
Air Conditioners Air Cooled	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.3 EER	ARI 340/360
		All other	Single Package	10.1 EER	
	≥ 135,000 Btu/h < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.7 EER	
		All other	Single Package	9.5 EER	
	≥ 240,000 Btu/h and < 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.5 EER 9.7 IPLV	
		All other	Split System and Single Package	9.3 EER 9.5 IPLV	
	≥ 760,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.2 EER 9.4 IPLV	
		All other	Split System and Single Package	9.0 EER 9.2 IPLV	

TABLE 6.8.1A (*continued*) Electronically Operated Unitary Air Conditioners and Condensing Units—Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air Conditioners, Water and Evaporatively Cooled	< 65,000 Btu/h	All Other	Split System and Single Package	12.1 EER	ARI 210/240
	≥ 65,000 Btu/h and < 135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.5 EER	ARI 340/360
		All other	Split System and Single Package	11.3 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER	
		All other	Split System and Single Package	10.8 EER	
	≥ 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	11.0 EER 10.3 IPLV	
		All other	Split System and Single Package	10.8 EER 10.1 IPLV	
Condensing Units, Air Cooled	≥ 135,000 Btu/h	–		10.1 IPLV 11.2 IPLV	ARI 365
Condensing Units, Water or Evaporatively Cooled	≥ 135,000 Btu/h	–		13.1 EER 13.1 IPLV	

[a] IPLVs and part load rating conditions are only applicable to equipment with capacity modulation.
[b] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
[c] Single-phase, air-cooled air-conditioners < 65,000 Btu/h are regulated by NAECA. SEER values are those set by NAECA.

TABLE 6.8.1B Electrically Operated Unitary and Applied Heat Pumps—Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air Cooled (Cooling Mode)	< 65,000 Btu/h[c]	All	Split System	12.0 SEER	ARI 210/240
			Single Package	12.0 SEER	
Through-the-Wall (Air Cooled, Cooling Mode)	≤ 30,000 Btu/h[c]	All	Split System	10.9 SEER 12 SEER (as of 1/23/2010)	
			Single Package	10.6 SEER 12.0 SEER (as of 1/23/2010)	
Small-Duct High-Velocity (Air Cooled, Cooling Mode)	< 65,000 Btu/h[c]	All	Split System	10 SEER	
Air Cooled (Cooling Mode)	≥ 65,000 Btu/h and <135,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	10.1 EER	ARI 340/360
		All other	Split System and Single Package	9.9 EER	
	≥ 135,000 Btu/h and < 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.3 EER	
		All other	Split System and Single Package	9.1 EER	
	≥ 240,000 Btu/h	Electric Resistance (or None)	Split System and Single Package	9.0 EER 9.2 IPLV	
		All other	Split System and Single Package	8.8 EER 9.0 IPLV	
Water-Source (Cooling Mode)	< 17,000 Btu/h	All	86ºF Entering Water	11.2 EER	ISO-13256-1
	≥ 17,000 Btu/h and < 65,000 Btu/h	All	86ºF Entering Water	12.0 EER	ISO-13256-1
	≥ 65,000 Btu/h and < 135,000 Btu/h	All	86°F Entering Water	12.0 EER	ISO-13256-1
Groundwater-Source (Cooling Mode)	< 135,000 Btu/h	All	59°F Entering Water	16.2 EER	ISO-13256-1

TABLE 6.8.1B (*continued*) Electrically Operated Unitary and Applied Heat Pumps — Minimum Efficiency Requirements

Equipment Type	Size Category	Heating Section Type	Sub-Category or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Ground Source (Cooling Mode)	< 135,000 Btu/h	All	77°F Entering Water	13.4 EER	ISO-13256-1
Air Cooled (Heating Mode)	< 65,000 Btu/h[c] (Cooling Capacity)	–	Split System	7.4 HSPF	ARI 210/240
			Single Package	7.4 HSPF	
Through-the-Wall, (Air Cooled, Heating Mode)	≤ 30,000 Btu/h[c] (cooling capacity)	–	Split System	7.1 HSPF 7.4 HSPF (as of 1/23/2010)	
			Single Package	7.0 HSPF 7.4 HSPF (as of 1/23/ 2010)	
Small-Duct High Velocity (Air Cooled, Heating Mode)	< 65,000 Btu/h[c] (cooling capacity)	–	Split System	6.8 HSPF	
Air Cooled (Heating Mode)	≥ 65,000 Btu/h and < 135,000 Btu/h (Cooling Capacity)	–	47°F db/43°F wb Outdoor air	3.2 COP	ARI 340/360
			17°F db/15°F wb Outdoor air	2.2 COP	
	≥ 135,000 Btu/h (Cooling Capacity)	–	47°F db/43°F wb Outdoor air	3.1 COP	
			17°F db/15°F wb Outdoor air	2.0 COP	
Water-Source (Heating Mode)	< 135,000 Btu/h (Cooling Capacity)	–	68°F Entering Water	4.2 COP	ISO-13256-1
Groundwater-Source (Heating Mode)	< 135,000 Btu/h (Cooling Capacity)	–	50°F Entering Water	3.6 COP	ISO-13256-1
Ground Source (Heating Mode)	< 135,000 Btu/h (Cooling Capacity)	–	32°F Entering Water	3.1 COP	ISO-13256-1

[a] IPLVs and Part load rating conditions are only applicable to equipment with capacity modulation.
[b] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
[c] Single-phase, air-cooled heat pumps < 65,000 Btu/h are regulated by NAECA. SEER and HSPF values are those set by NAECA

TABLE 6.8.1C Water Chilling Packages–Minimum Efficiency Requirements

Equipment Type	Size Category	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
Air Cooled, with Condenser, Electrically Operated	All Capacities		2.80 COP 3.05 IPLV	ARI 550/590
Air Cooled, without Condenser, Electrically Operated	All Capacities		3.10 COP 3.45 IPLV	
Water Cooled, Electrically Operated, Positive Displacement (Reciprocating)	All Capacities		4.20 COP 5.05 IPLV	ARI 550/590
Water Cooled, Electrically Operated, Positive Displacement (Rotary Screw and Scroll)	< 150 tons		4.45 COP 5.20 IPLV	ARI 550/590
	≥ 150 tons and < 300 tons		4.90 COP 5.60 IPLV	
	≥ 300 tons		5.50 COP 6.15 IPLV	
Water Cooled, Electrically Operated, Centrifugal	< 150 tons		5.00 COP 5.25 IPLV	ARI 550/590
	≥ 150 tons and < 300 tons		5.55 COP 5.90 IPLV	
	≥ 300 tons		6.10 COP 6.40 IPLV	
Air-Cooled Absorption Single Effect	All Capacities		0.60 COP	ARI 560
Water-Cooled Absorption Single Effect	All Capacities		0.70 COP	
Absorption Double Effect, Indirect-Fired	All Capacities		1.00 COP 1.05 IPLV	
Absorption Double Effect, Direct-Fired	All Capacities		1.00 COP 1.00 IPLV	

[a] The chiller equipment requirements do not apply for chillers used in low-temperature applications where the design leaving fluid temperature is <40°F.
[b] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

TABLE 6.8.1D Electrically Operated Packaged Terminal Air Conditioners, Packaged Terminal Heat Pumps, Single-Package Vertical Air Conditioners, Single -Package Vertical Heat Pumps, Room Air Conditioners, and Room Air Conditioner Heat Pumps–Minimum Efficiency Requirements

Equipment Type	Size Category	Subcategory or Rating Condition	Minimum Efficiency[a]	Test Procedure[b]
PTAC (Cooling Mode) New Construction	All Capacities	95°F db Outdoor air	12.5 – (0.213 × Cap/1000)[c] EER	ARI 310/380
PTAC (Cooling Mode) Replacements[b]	All Capacities	95°F db Outdoor air	10.9 – (0.213 × Cap/1000)c EER	
PTHP (Cooling Mode) New Construction	All Capacities	95°F db Outdoor air	12.3 – (0.213 × Cap/1000)[c] EER	
PTHP (Cooling Mode) Replacements[b]	All Capacities	95°F db Outdoor air	10.8 – (0.213 × Cap/1000)[c] EER	
PTHP (Heating Mode) New Construction	All Capacities		3.2 – (0.026 × Cap/1000)[c] COP	
PTHP (Heating Mode) Replacements[b]	All Capacities		3.2 – (0.026 × Cap/1000)[c] COP	
SPVAC (Cooling Mode)	All Capacities	95°F db/75°F wb Outdoor air	8.6 EER	ARI 390
SPVHP (Cooling Mode)	All Capacities	95°F db/75°F wb Outdoor air	8.6 EER	
SPVHP (Heating Mode)	All Capacities	47°F db/ 43°F wb Outdoor air	2.7 COP	
Room Air Conditioners, with Louvered Sides	< 6000 Btu/h		9.7 SEER	ANSI/ AHAM RAC-1
	≥ 6000 Btu/h and < 8000 Btu/h		9.7 SEER	
	≥ 8000 Btu/h and < 14,000 Btu/h		9.8 EER	
	≥14,000 Btu/h and <20,000 Btu/h		9.7 SEER	
	≥20,000 Btu/h		8.5 EER	
Room Air Conditioners, Without Louvered Sides	< 8000 Btu/h		9.0 EER	
	≥ 8000 Btu/h and < 20,000 Btu/h		8.5 EER	
	≥ 20,000 Btu/h		8.5 EER	
Room Air Conditioner Heat Pumps with Louvered Sides	< 20,000 Btu/h		9.0 EER	
	≥ 20,000 Btu/h		8.5 EER	
Room Air Conditioner Heat Pumps without Louvered Sides	< 14,000 Btu/h		8.5 EER	
	≥ 14,000 Btu/h		8.0 EER	
Room Air Conditioner, Casement Only	All Capacities		8.7 EER	
Room Air Conditioner, Casement−Slider	All Capacities		9.5 EER	

[a] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
[b] Replacement units must be factory labeled as follows: "MANUFACTURED FOR REPLACEMENT APPLICATIONS ONLY; NOT TO BE INSTALLED IN NEW CONSTRUCTION PROJECTS." Replacement efficiencies apply only to units with existing sleeves less than 16 in. high and less than 42 in. wide.
[c] Cap means the rated cooling capacity of the product in Btu/h. If the unit's capacity is less than 7000 Btu/h, use 7000 Btu/h in the calculation. If the unit's capacity is greater than 15,000 Btu/h, use 15,000 Btu/h in the calculation.

TABLE 6.8.1E Warm Air Furnaces and Combination Warm Air Furnaces/Air-Conditioning Units, Warm Air Duct Furnaces and Unit Heaters

Equipment Type	Size Category (Input)	Rating Condition or Subcategory	Minimum Efficiency[a]	Test Procedure[b]
Warm Air Furnace, Gas-Fired	< 225,000 Btu/h		78% AFUE or 80% E_t[d]	DOE 10 CFR Part 430 or ANSI Z21.47
	≥ 225,000 Btu/h	Maximum Capacity[d]	80% E_c[c]	ANSI Z21.47
Warm Air Furnace, Oil-Fired	< 225,000 Btu/h		78% AFUE or 80% E_t[d]	DOE 10 CFR Part 430 or UL 727
	≥ 225,000 Btu/h	Maximum Capacity[e]	81% E_t[f]	UL 727
Warm Air Duct Furnaces, Gas- Fired	All Capacities	Maximum Capacity[e]	80% E_c[g]	ANSI Z83.9
Warm Air Unit Heaters, Gas-Fired	All Capacities	Maximum Capacity[e]	80% E_c[g]	ANSI Z83.8
Warm Air Unit Heaters, Oil-Fired	All Capacities	Maximum Capacity[e]	80% E_c [g]	UL 731

[a] E_t = *thermal efficiency*. See test procedure for detailed discussion.
[b] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
[c] E^c = combustion *efficiency*. Units must also include an interrupted or intermittent ignition device (IID), have jacket losses not exceeding 0.75% of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.
[d] Combination units not covered by NAECA (3-phase power or cooling capacity greater than or equal to 65,000 Btu/h) may comply with either rating.
[e] Minimum and maximum ratings as provided for and allowed by the unit's controls.
[f] E_t = thermal *efficiency*. Units must also include an interrupted or intermittent ignition device (IID), have jacket losses not exceeding 0.75% of the input rating, and have either power venting or a flue damper. A vent damper is an acceptable alternative to a flue damper for those furnaces where combustion air is drawn from the conditioned space.
[g] E_c = combustion *efficiency* (100% less flue losses). See test procedure for detailed discussion.

TABLE 6.8.1F Gas- and Oil-Fired Boilers–Minimum Efficiency Requirements

Equipment Type[a]	Size Category (Input)	Subcategory or Rating Condition	Minimum Efficiency[b]	Test Procedure[c]
Boilers, Gas-Fired	< 300,000 Btu/h	Hot Water	80% AFUE	DOE 10 CFR Part 430
		Steam	75% AFUE	
	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h	Maximum Capacity[d]	75% E_t[b]	H.I. Htg Boiler Std
	> 2,500,000 Btu/h[a]	Hot Water	80% E_c	
	> 2,500,000 Btu/h[a]	Steam	80% E_c	
Boilers, Oil-Fired	< 300,000 Btu/h		80% AFUE	DOE 10 CFR Part 430
	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h	Maximum Capacity[d]	78% E_t [b]	H.I. Htg Boiler Std.
	> 2,500,000 Btu/h[a]	Hot Water	83% E_c	
	> 2,500,000 Btu/h[a]	Steam	83%E_c	
Oil-Fired (Residual)	≥ 300,000 Btu/h and ≤ 2,500,000 Btu/h	Maximum Capacity[d]	78% *Et*[b]	H.I. Htg Boiler Std.
	> 2,500,000 Btu/ha	Hot Water	83% E_c	
	> 2,500,000 Btu/ha	Steam	83% E_c	

[a] These requirements apply to boilers with rated input of 8,000,000 Btu/h or less that are not packaged boilers, and to all packaged boilers. Minimum *efficiency* requirements for boilers cover all capacities of packaged boilers.
[b] E_t = thermal *efficiency*. See reference document for detailed information.
[c] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.
[d] Minimum and maximum ratings as provided for and allowed by the unit's controls.

TABLE 6.8.1G Performance Requirements for Heat Rejection Equipment

Equipment Type	Total system Heat Rejection Capacity at Rated Conditions	Subcategory or Rating Condition	Performance Required[a,b]	Test Procedure [c]
Propeller or Axial Fan Cooling Towers	All	95°F Entering Water 85°F Leaving Water 75°F wb *Outdoor air*	≥ 38.2gpm/hp	CTI ATC-105
Centrifugal Fan Cooling Towers	All	95°F Entering Water 85°F Leaving Water 75°F wb *Outdoor air*	≥ 20.0 gpm/hp	CTI ATC-105
Air-Cooled Condensers	All	125°F Condensing Temperature R-22 Test Fluid 190°F Entering Gas Temperature 15°F Subcooling 95°F Entering db	≥ 176,000 Btu/h·hp	ARI 460

[a] For purposes of this table, cooling tower performance is defined as the maximum flow rating of the tower divided by the fan nameplate rated motor power.
[b] For purposes of this table, air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the fan nameplate rated motor power.
[c] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

TABLE 6.8.1H Minimum Efficiencies for Central Chillers <150 tons

Centrifugal Chillers < 150 tons COP_{std} = 5.00; $IPLV_{std}$ = 5.25														
			Condenser Flow Rate											
			2 gpm/ton		2.5 gpm/ton		3 gpm/ton		4 gpm/ton		5 gpm/ton		6 gpm/ton	
Leaving Chilled Water Temperature (°F)	Entering Condenser Water Temperature (°F)	LIFT[a] (°F)	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]
40	75	35	5.11	5.35	5.33	5.58	5.48	5.73	5.67	5.93	5.79	6.06	5.88	6.15
40	80	40	4.62	4.83	4.92	5142	5.09	5.32	5.27	5.52	5.38	5.63	5.45	5.70
40	85	45	3.84	4.01	4.32	4.52	4.58	4.79	4.84	5.06	4.98	5.20	5.06	5.29
41	75	34	5.19	5.43	5.41	5.66	5.56	5.81	5.75	6.02	5.89	6.16	5.99	6.26
41	80	39	4.73	4.95	5.01	5.24	5.17	5.41	5.35	5.60	5.46	5.71	5.53	5.78
41	85	44	4.02	4.21	4.46	4.67	4.70	4.91	4.94	5.17	5.06	5.30	5.14	5.38
42	75	33	5.27	5.51	5.49	5.74	5.64	5.90	5.85	6.12	6.00	6.27	6.11	6.39
42	80	38	4.84	5.06	5.10	5.33	5.25	5.49	5.43	5.67	5.53	5.79	5.61	5.87
42	85	43	4.19	4.38	4.59	4.80	4.81	5.03	5.03	5.26	5.15	5.38	5.22	5.46
43	75	32	5.35	5.59	5.57	5.82	5.72	5.99	5.95	6.23	6.11	6.39	6.23	6.52
43	80	37	4.94	5.16	5.18	5.42	5.32	5.57	5.50	5.76	5.62	5.87	5.70	5.96
43	85	42	4.35	4.55	4.71	4.93	4.91	5.13	5.12	5.35	5.23	5.47	5.30	5.54
44	75	31	5.42	5.67	5.65	5.91	5.82	6.08	6.07	6.34	6.24	6.53	6.37	6.67
44	80	36	5.03	5.26	5.26	5.50	5.40	5.65	5.58	5.84	5.70	5.96	5.79	6.05
44	85	41	4.49	4.69	4.82	5.04	5.00	5.25	5.20	5.43	5.30	5.55	5.38	5.62
45	75	30	5.50	5.75	5.74	6.00	5.92	6.19	6.19	6.47	6.38	6.68	6.53	6.83
45	80	35	5.11	5.35	5.33	5.58	5.48	5.73	5.67	5.93	5.79	6.06	5.88	6.15
45	85	40	4.62	4.83	4.92	5.14	5.09	5.31	5.27	5.52	5.38	5.63	5.45	5.70
46	75	29	5.58	5.84	5.83	6.10	6.03	6.30	6.32	6.61	6.54	6.84	6.70	7.00
46	80	34	5.19	5.43	5.41	5.66	5.56	5.81	5.75	6.02	5.89	6.16	5.99	6.26
46	85	39	4.73	4.95	5.01	5.24	5.17	5.41	5.35	5.60	5.46	5.71	5.53	5.78
47	75	28	5.66	5.92	5.93	6.20	6.15	6.43	6.47	6.77	6.71	7.02	6.88	7.20
47	80	33	5.27	5.51	5.49	5.74	5.64	5.90	5.85	6.12	6.00	6.27	6.11	6.39
47	85	38	4.84	5.06	5.10	5.33	5.25	5.49	5.43	5.67	5.53	5.79	5.61	5.87
48	75	27	5.75	6.02	6.04	6.32	6.28	6.56	6.64	6.94	6.89	7.21	7.09	7.41
48	80	32	5.35	5.59	5.57	5.82	5.72	5.99	5.95	6.23	6.11	6.39	6.23	6.52
48	85	37	4.94	5.16	5.18	5.42	5.32	5.57	5.50	5.76	5.62	5.87	5.70	5.96
Condenser DT[b]			14.04		11.23		9.36		7.02		5.62		4.68	

[a] LIFT = Entering Condenser Water Temperature – Leaving Chilled Water Temperature

[b] Condenser DT = Leaving Condenser Water Temperature (°F) – Entering Condenser Water Temperature (°F)

[c] All NPLV values shown are NPLV except at conditions of 3 gpm/ton Condenser Flow Rate with 44°F Leaving Chilled Water Temperature and 85°F Entering Condenser Water Temperature which is IPLV

$K_{adj} = 6.1507 - 0.30244(X) + 0.0062692(X)^2 - 0.000045595(X)^3$

where X = Condenser DT + LIFT

$COP_{adj} = K_{adj} * COP_{std}$

TABLE 6.8.1I Minimum Efficiencies for Central Chillers ≥ 150 tons, ≤ 300 tons

Centrifugal Chillers ≥150 tons, ≤300 tons COP_{std} = 5.55; $IPLV_{std}$ = 5.90														
			Condenser Flow Rate											
			2 gpm/ton		2.5 gpm/ton		3 gpm/ton		4 gpm/ton		5 gpm/ton		6 gpm/ton	
Leaving Chilled Water Temperature (°F)	Entering Condenser Water Temperature (°F)	LIFT[a] (°F)	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]
40	75	35	5.65	6.03	5.90	6.29	6.05	6.46	6.26	6.68	6.40	6.83	6.51	6.94
40	80	40	5.10	5.44	5.44	5.80	5.62	6.00	5.83	6.22	5.95	6.35	6.03	6.43
40	85	45	4.24	4.52	4.77	5.09	5.06	5.40	5.35	5.71	5.50	5.87	5.59	5.97
41	75	34	5.74	6.13	5.80	6.38	6.14	6.55	6.36	6.79	6.51	6.95	6.62	7.06
41	80	39	5.23	5.58	5.54	5.91	5.71	6.10	5.91	6.31	6.03	6.44	6.11	6.52
41	85	44	4.45	4.74	4.93	5.26	5.19	5.54	5.46	5.82	5.60	5.97	5.69	6.07
42	75	33	5.83	6.22	6.07	6.47	6.23	6.65	6.47	6.90	6.63	7.07	6.75	7.20
42	80	38	5.35	5.71	5.64	6.01	5.80	6.19	6.00	6.40	6.12	6.53	6.20	6.62
42	85	43	4.63	4.94	5.08	5.41	5.31	5.67	5.56	5.93	5.69	6.07	5.77	6.16
43	75	32	5.91	6.31	6.15	6.56	6.33	6.75	6.58	7.02	6.76	7.21	6.89	7.35
43	80	37	5.46	5.82	5.73	6.11	5.89	6.28	6.08	6.49	6.21	6.62	6.30	6.72
43	85	42	4.81	5.13	5.21	5.55	5.42	5.79	5.66	6.03	5.78	6.16	5.86	6.25
44	75	31	6.00	6.40	6.24	6.66	6.43	6.86	6.71	7.15	6.90	7.36	7.05	7.52
44	80	36	5.56	5.93	5.81	6.20	5.97	6.37	6.17	6.58	6.30	6.72	6.40	6.82
44	85	41	4.96	5.29	5.33	5.68	5.55	5.90	5.74	6.13	5.86	6.26	5.94	6.34
45	75	30	6.08	6.49	6.34	6.76	6.54	6.98	6.84	7.30	7.06	7.53	7.22	7.70
45	80	35	5.65	6.03	5.90	6.29	6.05	6.46	6.26	6.68	6.40	6.83	6.51	6.94
45	85	40	5.10	5.44	5.44	5.80	5.62	6.00	5.83	6.22	5.95	6.35	6.03	6.43
46	75	29	6.17	6.58	6.44	6.87	6.66	7.11	6.99	7.46	7.23	7.71	7.40	7.90
46	80	34	5.74	6.13	5.80	6.38	6.14	6.55	6.36	6.79	6.51	6.95	6.62	7.06
46	85	39	5.23	5.58	5.54	5.91	5.71	6.10	5.91	6.31	6.03	6.44	6.11	6.52
47	75	28	6.26	6.68	6.56	6.99	6.79	7.24	7.16	7.63	7.42	7.91	7.61	8.11
47	80	33	5.83	6.21	6.07	6.47	6.23	6.64	6.47	6.90	6.63	7.07	6.75	7.20
47	85	38	5.35	5.70	5.64	6.01	5.80	6.19	6.00	6.40	6.12	6.52	6.20	6.61
48	75	27	6.36	6.78	6.68	7.12	6.94	7.40	7.34	7.82	7.62	8.13	7.83	8.35
48	80	32	5.91	6.30	6.15	6.56	6.33	6.75	6.58	7.02	6.76	7.21	6.89	7.35
48	85	37	5.46	5.82	5.73	6.10	5.89	6.28	6.08	6.49	6.21	6.62	6.30	6.71
Condenser DT[b]			14.04		11.23		9.36		7.02		5.62		4.68	

[a] LIFT = Entering Condenser Water Temperature – Leaving Chilled Water Temperature

[b] Condenser DT = Leaving Condenser Water Temperature (°F) – Entering Condenser Water Temperature (°F)

[c] All NPLV values shown are NPLV except at conditions of 3 gpm/ton Condenser Flow Rate with 44°F Leaving Chilled Water Temperature and 85°F Entering Condenser Water Temperature which is IPLV

$K_{adj} = 6.1507 - 0.30244(X) + 0.0062692(X)^2 - 0.000045595(X)^3$

where X = Condenser DT + LIFT

$COP_{adj} = K_{ad}j * COP_{std}$

TABLE 6.8.1J Minimum Efficiencies for Centrifugal Chillers >300 tons

Centrifugal Chillers >300 tons COP_{std} = 6.10; $IPLV_{std}$ = 6.40														
			Condenser Flow Rate											
			2 gpm/ton		2.5 gpm/ton		3 gpm/ton		4 gpm/ton		5 gpm/ton		6 gpm/ton	
Leaving Chilled Water Temperature (°F)	Entering Condenser Water Temperature (°F)	LIFT[a]	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]	COP	NPLV[c]
40	75	35	6.23	6.55	6.50	6.83	6.68	7.01	6.91	7.26	7.06	7.42	7.17	7.54
40	80	40	5.63	5.91	6.00	6.30	6.20	6.52	6.43	6.76	6.56	6.89	6.65	6.98
40	85	45	4.68	4.91	5.26	5.53	5.58	5.86	5.90	6.20	6.07	6.37	6.17	6.48
41	75	34	6.33	6.65	6.60	6.93	6.77	7.12	7.02	7.37	7.18	7.55	7.30	7.67
41	80	39	5.77	6.06	6.11	6.42	6.30	6.62	6.52	6.85	6.65	6.99	6.74	7.08
41	85	44	4.90	5.15	5.44	5.71	5.72	6.01	6.02	6.33	6.17	6.49	6.27	6.59
42	75	33	6.43	6.75	6.69	7.03	6.87	7.22	7.13	7.49	7.31	7.68	7.44	7.82
42	80	38	5.90	6.20	6.21	6.53	6.40	6.72	6.61	6.95	6.75	7.09	6.84	7.19
42	85	43	5.11	5.37	5.60	5.88	5.86	6.16	6.13	6.44	6.28	6.59	6.37	6.69
43	75	32	6.52	6.85	6.79	7.13	6.98	7.33	7.26	7.63	7.45	7.83	7.60	7.98
43	80	37	6.02	6.32	6.31	6.63	6.49	6.82	6.71	7.05	6.85	7.19	6.94	7.30
43	85	42	5.30	5.57	5.74	6.03	5.98	6.28	6.24	6.55	6.37	6.70	6.46	6.79
44	75	31	6.61	6.95	6.89	7.23	7.09	7.45	7.40	7.77	7.61	8.00	7.77	8.16
44	80	36	6.13	6.44	6.41	6.73	6.58	6.92	6.81	7.15	6.95	7.30	7.05	7.41
44	85	41	5.47	5.75	5.87	6.17	6.10	6.40	6.33	6.66	6.47	6.79	6.55	6.89
45	75	30	6.71	7.05	6.99	7.35	7.21	7.58	7.55	7.93	7.78	8.18	7.96	8.36
45	80	35	6.23	6.55	6.50	6.83	6.68	7.01	6.91	7.26	7.06	7.42	7.17	7.54
45	85	40	5.63	5.91	6.00	6.30	6.20	6.52	6.43	6.76	6.56	6.89	6.65	6.98
46	75	29	6.80	7.15	7.11	7.47	7.35	7.72	7.71	8.10	7.97	8.37	8.16	8.58
46	80	34	6.33	6.65	6.60	6.93	6.77	7.12	7.02	7.37	7.18	7.55	7.30	7.67
46	85	39	5.77	6.06	6.11	6.42	6.30	6.62	6.52	6.85	6.65	6.99	6.74	7.08
47	75	28	6.91	7.26	7.23	7.60	7.49	7.87	7.89	8.29	8.18	8.59	8.39	8.82
47	80	33	6.43	6.75	6.69	7.03	6.87	7.22	7.13	7.49	7.31	7.68	7.44	7.82
47	85	38	5.90	6.20	6.21	6.53	6.40	6.72	6.61	6.95	6.75	7.09	6.84	7.19
48	75	27	7.01	7.37	7.36	7.74	7.65	8.04	8.09	8.50	8.41	8.83	8.64	9.08
48	80	32	6.52	6.85	6.79	7.13	6.98	7.33	7.26	7.63	7.45	7.83	7.60	7.98
48	85	37	6.02	6.32	6.31	6.63	6.49	6.82	6.71	7.05	6.85	7.19	6.94	7.30
Condenser DT[b]			14.04		11.23		9.36		7.02		5.62		4.68	

[a] LIFT = Entering Condenser Water Temperature – Leaving Chilled Water Temperature

[b] Condenser DT = Leaving Condenser Water Temperature (°F) – Entering Condenser Water Temperature (°F)

[c] All NPLV values shown are NPLV except at conditions of 3 gpm/ton Condenser Flow Rate with 44°F Leaving Chilled Water Temperature and 85°F Entering Condenser Water Temperature which is IPLV

$K_{adj} = 6.1507 - 0.30244(X) + 0.0062692(X)^2 - 0.000045595(X)^3$

where X = Condenser DT + LIFT

$COP_{adj} = K_{adj} * COP_{std}$

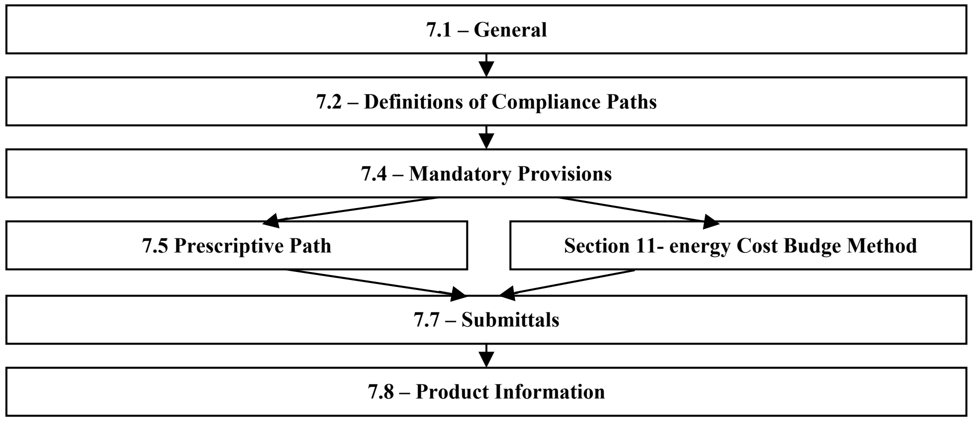
6.8.2 Reserved

TABLE 6.8.3 Minimum Pipe Insulation[a]

Fluid	≤1.5”	>1.5”- 4”[d]	>4”[d]
Steam	1 ½	3	4
Service Hot Water	1	2	2
Chilled Water, Brine or Refrigerant	1	1 ½	2

[a] Based on insulation having a conductivity (k) not exceeding 0.27 Btu per in./h·ft^2·°F.
[b] These thicknesses are based on energy efficiency considerations only. Additional insulation is sometimes required relative to safety issues/surface temperature.
[c] These thickness are based on energy efficiency considerations only. Issues such as water vapor permeability or surface condensation sometimes require vapor retarders or additional insulation.
[d] Nominal pipe size.

7. SERVICE WATER HEATING



7.1 General

7.1.1 Service Water Heating Scope.

7.1.1.1 New Buildings. Service water heating *systems* and *equipment* shall comply with the requirements of this section as described in Section 7.2.

7.1.1.2 Additions to Existing Buildings. Service water heating *systems* and *equipment* shall comply with the requirements of this section.

> **Exception to 7.1.1.2:** When the service water heating to an *addition* is provided by existing service water heating systems and equipment, such systems and equipment shall not be required to comply with this code. However, any new systems or equipment installed must comply with specific requirements applicable to those systems and equipment.

7.1.1.3 Alterations to Existing Buildings. Building service water heating equipment installed as a direct replacement for *existing building* service water heating equipment shall comply with the requirements of Section 7 applicable to the equipment being replaced. New and replacement piping shall comply with 7.4.3.

> **Exception to 7.1.1.3:** Compliance shall not be required where there is insufficient space or access to meet these requirements.

7.2 Compliance Path(s)

7.2.1 Compliance shall be achieved by meeting the requirements of 7.1, General; 7.4, Mandatory Provisions; 7.5, Prescriptive Path; 7.7, Submittals; and 7.8, Product Information.

7.2.2 Projects using the Energy Cost Budget Method (Section 11) for demonstrating compliance with the code shall meet the requirements of 7.4 (Mandatory Provisions) in conjunction with Section 11 (Energy Cost Budget Method).

7.3 Simplified/Small Building Option: (Not Used)

7.4 Mandatory Provisions

7.4.1 Load Calculations. Service water heating *system* design loads for the purpose of sizing *systems* and *equipment* shall be determined in accordance with *manufacturers'* published sizing guidelines or generally accepted engineering standards and handbooks acceptable to the *adopting authority* (e.g., ASHRAE Handbook—HVAC Applications).

7.4.2 Equipment Efficiency. All water heating *equipment*, hot water supply boilers used solely for heating potable water, pool heaters, and hot water storage tanks shall meet the criteria listed in Table 7.8. Where multiple criteria are listed, all criteria shall be met. Omission of minimum performance requirements for certain classes of *equipment* does not preclude use of such *equipment* where appropriate. Equipment not listed in Table 7.8 has no minimum performance requirements.

> **Exception to 7.4.2:** All water heaters and hot water supply boilers having more than 140 gal of storage capacity are not required to meet the standby loss (SL) requirements of Table 7.8 when

(a) the tank surface is thermally insulated to R-12.5, and

(b) a standing pilot light is not installed, and

(c) gas- or oil-fired storage water heaters have a flue damper or fan-assisted combustion.

7.4.3 Service Hot Water Piping Insulation. The following piping shall be insulated to levels shown in Section 6, Table 6.8.3:

(a) Recirculating system piping, including the supply and return piping of a circulating tank type water heater.

(b) All piping for a constant temperature nonrecirculating storage *system* above 20 gallons. For service hot water heating up to 20 gallons, only the first 8 ft of outlet piping is required to be insulated.

(c) The inlet pipe between the storage tank and a heat trap in a nonrecirculating storage *system*.

(d) Pipes that are externally heated (such as heat trace or impedance heating).

7.4.4 Service Water Heating System Controls

7.4.4.1 Temperature Controls. Temperature controls shall be provided that allow for storage temperature adjustment from 120°F or lower to a maximum temperature compatible with the intended use.

Exception to 7.4.4.1: When the *manufacturer's* installation instructions specify a higher minimum thermostat setting to minimize condensation and resulting corrosion.

7.4.4.2 Temperature Maintenance Controls. Systems designed to maintain usage temperatures in hot water pipes, such as recirculating hot water systems or heat trace, shall be equipped with automatic time switches or other controls that can be set to switch off the usage temperature maintenance system during extended periods when hot water is not required.

7.4.4.3 Outlet Temperature Controls. Temperature controlling means shall be provided to limit the maximum temperature of water delivered from lavatory faucets in public facility restrooms to 110°F.

7.4.4.4 Circulating Pump Controls. When used to maintain storage tank water temperature, recirculating pumps shall be equipped with controls limiting operation to a period from the start of the heating cycle to a maximum of five minutes after the end of the heating cycle.

7.4.5 Pools

7.4.5.1 Pool Heaters. Pool heaters shall be equipped with a readily accessible on-off switch to allow shutting off the heater without adjusting the thermostat setting. Pool heaters fired by natural gas shall not have continuously burning pilot lights.

7.4.5.2 Pool Covers. Heated pools shall be equipped with a vapor retardant pool cover on or at the water surface. Pools heated to more than 90°F shall have a pool cover with a minimum insulation value of R-12.

Exception to 7.4.5.2: Pools deriving over 60% of the energy for heating from *site-recovered energy* or *solar energy source*.

7.4.5.3 Time Switches. Time switches shall be installed on swimming pool heaters and pumps.

Exceptions to 7.4.5.3:

(a) Where public health standards require 24-hour pump operation.

(b) Where pumps are required to operate solar and waste heat recovery pool heating *systems*.

7.4.6 Heat Traps. Vertical pipe risers serving storage water heaters and storage tanks not having integral heat traps and serving a nonrecirculating system shall have heat traps on both the inlet and outlet piping as close as practical to the storage tank. A heat trap is a means to counteract the natural convection of heated water in a vertical pipe run. The means is either a device specifically designed for the purpose or an arrangement of tubing that forms a loop of 360 degrees or piping that from the point of connection to the water heater (inlet or outlet) includes a length of piping directed downward before connection to the vertical piping of the supply water or hot water distribution system, as applicable.

7.5 Prescriptive Path

7.5.1 Space Heating and Water Heating. The use of a gas-fired or oil-fired space heating boiler system otherwise complying with Section 6 to provide the total space heating and water heating for a building is allowed when one of the following conditions is met.

(a) The single space heating boiler, or the component of a modular or multiple boiler system that is heating the service water, has a standby loss in Btu/h not exceeding

$$(13.3 \times pmd + 400) / n$$

where *pmd* is the probable maximum demand in gal/h, determined in accordance with the procedures described in generally accepted engineering standards and handbooks, and n is the fraction of the year when the outdoor daily mean temperature is greater than 64.9°F. The standby loss is to be determined for a test period of 24 hours duration while maintaining a boiler water temperature of at least 90°F above ambient, with an ambient temperature between 60°F and 90°F. For a boiler with a modulating burner, this test shall be conducted at the lowest input.

(b) It is demonstrated to the satisfaction of the *authority having jurisdiction* that the use of a single heat source will consume less energy than separate units.

(c) The energy input of the combined boiler and water heater system is less than 150,000 Btu/h.

7.5.2 Service Water Heating Equipment. Service water heating *equipment* used to provide the additional function of space heating as part of a combination (integrated) *system* shall satisfy all stated requirements for the service water heating *equipment*.

7.6 Alternative Compliance Path (Not Used)

7.7 Submittals

7.7.1 General. *Authority having jurisdiction* may require submittal of compliance documentation and supplemental information, in accord with Section 4.2.2 of this code.

7.8 Product Information TABLE

7.8 Performance Requirements for Water Heating Equipment

Equipment Type	Size Category (Input)	Subcategory or Rating Condition	Performance Required[a]	Test Procedure[b]
Electric Water Heaters	≤ 12 kW	Resistance ≥ 20 gal	0.93-0.00132V EF	DOE 10 CFR Part 430
	> 12 kW	Resistance ≥ 20 gal	20 + 35 √V SL, Btu/h	ANSI Z21.10.3
	≤ 24 Amps and ≤ 250 Volts	Heat Pump	0.93-0.00132V EF DOE	DOE 10 CFR Part 430
Gas Storage Water Heaters	≤ 75,000 Btu/h	≥ 20 gal	0.62-0.0019V EF	DOE 10 CFR Part 430
	> 75,000 Btu/h	< 4000 (Btu/h)/gal	80% E_t (Q/800 + 110 √V) SL, Btu/h	ANSI Z21.10.3
Gas Instantaneous Water Heaters	> 50,000 Btu/h and < 200,000 Btu/h	≥ 4000 (Btu/h)/gal and <2 gal	0.62-0.0019V EF	DOE 10 CFR Part 430
	≥ 200,000 Btu/h[c]	≥ 4000 (Btu/h)/gal and < 10 gal	80% E_t	ANSI Z21.10.3
	≥ 200,000 Btu/h	≥ 4000 (Btu/h)/gal and ≥ 10 gal	80% E_t (Q/800 + 110 √V) SL, Btu/h	
Oil Storage Water Heaters	≤ 105,000 Btu/h	≥ 20 gal	0.59-0.0019V EF	DOE 10 CFR Part 430
	> 105,000 Btu/h	< 4000 (Btu/h)/gal	78% E_t (Q/800 + 110 √V) SL, Btu/h	ANSI Z21.10.3
Oil Instantaneous Water Heaters	≤ 210,000 Btu/h	≥ 4000 (Btu/h)/gal and <2 gal	0.59-0.0019V EF	DOE 10 CFR Part 430
	> 210,000 Btu/h	≥ 4000 (Btu/h)/gal and <10 gal	80% E_t	ANSI Z21.10.3
	> 210,000 Btu/h	≥ 4000 (Btu/h)/gal and ≥10 gal	78% E_t (Q/800 + 110 √V) SL, Btu/h	
Hot Water Supply Boilers, Gas and Oil	≥ 300,000 Btu/h and < 12,500,000 Btu/h	≥ 4000 (Btu/h)/gal and <10 gal	80% E_t	ANSI Z21.10.3
Hot Water Supply Boilers, Gas		≥ 4000 (Btu/h)/gal and ≥10 gal	80% E_t (Q/800 + 110 √V) SL, Btu/h	
Hot Water Supply Boilers, Oil		≥ 4000 (Btu/h)/gal and ≥10 gal	78% E_f(Q/800 + 110 √V) SL, Btu/h	
Pool Heaters Oil and Gas	All		78% E_t	ASHRAE 146
Heat Pump Pool Heaters	All		4.0 COP	ASHRAE 146
Unfired Storage Tanks	All		R-12.5	(none)

[a] Energy factor (EF) and thermal *efficiency* (Et) are minimum requirements, while standby loss (SL) is maximum Btu/h based on a 70°F temperature difference between stored water and ambient requirements. In the EF equation, V is the rated volume in gallons. In the SL equation, V is the rated volume in gallons and Q is the nameplate input rate in Btu/h.

[b] Section 12 contains a complete specification, including the year version, of the referenced test procedure.

[c] Instantaneous water heaters with input rates below 200,000 Btu/h must comply with these requirements if the water heater is designed to heat water to temperatures 180°F or higher.

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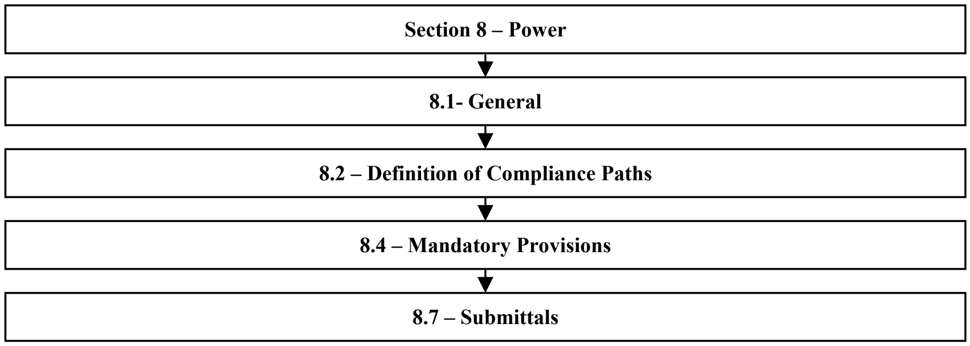
8. POWER



8.1 General. This section applies to all building power distribution *systems*.

8.2 Compliance Path(s)

8.2.1 Power distribution systems in all projects shall comply with the requirements of 8.1, General; 8.4, Mandatory Provisions; and 8.7, Submittals.

8.3 Simplified/Small Building Option: (Not Used)

8.4 Mandatory Provisions

8.4.1 Voltage Drop

8.4.1.1 Feeders. *Feeder conductors* shall be sized for a maximum *voltage drop* of 2% at design load.

8.4.1.2 Branch Circuits. *Branch circuit* conductors shall be sized for a maximum *voltage drop* of 3% at design load.

8.5 Prescriptive Path (Not Used)

8.6 Alternative Compliance Path (Not Used)

8.7 Submittals:

8.7.1 Drawings. Construction documents shall require that within 30 days after the date of system acceptance, record drawings of the actual installation shall be provided to the building owner, including

(a) a single-line diagram of the building electrical distribution system and

(b) floor plans indicating location and area served for all distribution.

8.7.2 Manuals. Construction documents shall require that an operating manual and maintenance manual be provided to the building owner. The manuals shall include, at a minimum, the following:

(a) Submittal data stating *equipment* rating and selected options for each piece of *equipment* requiring maintenance.

(b) Operation manuals and maintenance manuals for each piece of *equipment* requiring maintenance. Required routine maintenance actions shall be clearly identified.

(c) Names and addresses of at least one qualified *service agency*.

(d) A complete narrative of how each system is intended to operate.

(Enforcement agencies should only check to be sure that the construction documents require this information to be transmitted to the owner and should not expect copies of any of the materials.)

8.8 Product Information (Not Used)

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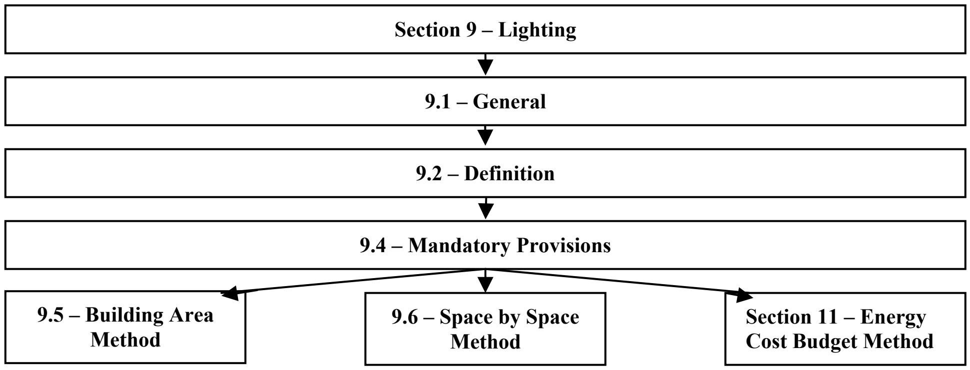
9. LIGHTING



9.1 General

9.1.1 Scope: This section shall apply to the following:

(a) interior spaces of *buildings*;

(b) exterior building features, including facades, illuminated roofs, architectural features, entrances, exits, loading docks, and illuminated canopies; and

(c) exterior building grounds lighting provided through the *building's* electrical *service*.

Exceptions to 9.1.1:

(a) emergency lighting that is automatically off during normal building operation,

(b) lighting within living units,

(c) lighting that is specifically designated as required by a health or life safety statute, ordinance, or regulation,

(d) decorative gas lighting systems.

9.1.2 Lighting Alterations. The replacement of lighting *systems* in any building space shall comply with the lighting power density requirements of Section 9 applicable to that space. New lighting *systems* shall comply with the applicable lighting power density requirements of Section 9. Any new *control devices* as a direct replacement of existing *control devices* shall comply with the specific requirements of 9.4.1.2(b).

Exception to 9.1.2: For *alterations* that replace less than 50% of the *luminaires* in a *space* only those *luminaires* that are replaced need comply with this section.

9.1.3 Installed Interior Lighting Power. The *installed interior lighting power* shall include all power used by the *luminaires*, including *lamps*, *ballasts*, current regulators, and *control devices* except as specifically exempted in 9.2.2.3.

Exception to 9.1.3: If two or more independently operating lighting systems in a space are capable of being controlled to prevent simultaneous user operation, the installed interior lighting power shall be based solely on the lighting system with the highest wattage.

9.1.4 Luminaire Wattage. Luminaire wattage incorporated into the installed interior lighting power shall be determined in accordance with the following criteria:

(a) The wattage of incandescent or tungsten-halogen luminaires with medium screw base sockets and not containing permanently installed ballasts shall be the maximum labeled wattage of the luminaire.

(b) The wattage of luminaires with permanently installed or remote ballasts or *transformers* shall be the operating input wattage of the maximum lamp/ auxiliary combination based on values from the auxiliary *manufacturer's* literature or recognized testing laboratories.

(c) The wattage of line-voltage lighting track and plug-in busway that allow the addition and/or relocation of luminaires without altering the wiring of the system shall be the specified wattage of the luminaires included in the system with a minimum of 30 W/lin ft.

(d) The wattage of low-voltage lighting track, cable conductor, rail conductor, and other flexible lighting systems that allow the addition and/or relocation of luminaires without altering the wiring of the system shall be the specified wattage of the transformer supplying the system.

(e) The wattage of all other miscellaneous lighting equipment shall be the specified wattage of the lighting equipment.

9.2 Compliance Path(s)

9.2.1 Lighting systems and equipment shall comply with 9.1, General; 9.4, Mandatory Provisions; and the prescriptive requirements of either:

(a) 9.5, Building Area Method, or

(b) 9.6, Space-by-Space Method.

9.2.2 Prescriptive Requirements

9.2.2.1 The Building Area Method for determining the *interior lighting power allowance*, described in 9.5, is a simplified approach for demonstrating compliance.

9.2.2.2 The Space-by-Space Method, described in 9.6, is an alternative approach that allows greater flexibility.

9.2.2.3 Interior Lighting Power. The *interior lighting power allowance* for a *building* or a separately metered or permitted portion of a *building* shall be determined by either the Building Area Method described in 9.5 or the Space-by-Space Method described in 9.6. Trade-offs of *interior lighting power allowance* among portions of the *building* for which a different method of calculation has been used are not permitted. The *installed interior lighting power* identified in accordance with 9.1.3 shall not exceed the *interior lighting power* allowance developed in accordance with 9.5 or 9.6.

Exceptions to 9.2.2.3: The following *lighting equipment* and applications shall not be considered when determining the *interior lighting power allowance* developed in accordance with 9.5 or 9.6, nor shall the wattage for such lighting be included in the *installed interior lighting power* identified in accordance with 9.1.3. However, any such lighting shall not be exempt unless it is an addition to general lighting and is controlled by an independent *control device*.

(a) Display or accent lighting that is an essential element for the function performed in galleries, museums, and monuments.

(b) Lighting that is integral to *equipment* or instrumentation and is installed by it *manufacturer*.

(c) Lighting specifically designed for use only during medical or dental procedures and lighting integral to medical *equipment*.

(d) Lighting integral to both open and glass-enclosed refrigerator and freezer cases.

(e) Lighting integral to food warming and food preparation *equipment*.

(f) Lighting for plant growth or maintenance.

(g) Lighting in spaces specifically designed for use by the visually impaired.

(h) Lighting in *retail* display windows, provided the display area is enclosed by ceiling-height partitions.

(i) Lighting in interior spaces that have been specifically designated as a registered interior *historic* landmark.

(j) Lighting that is an integral part of advertising or directional signage.

(k) Exit signs.

(l) Lighting that is for sale or lighting educational demonstration *systems*.

(m) Lighting for theatrical purposes, including performance, stage, and film and video production.

(n) Lighting for television broadcasting in sporting activity areas.

(o) Casino gaming areas.

9.3 (Not Used)

9.4 Mandatory Provisions

9.4.1 Lighting Control

9.4.1.1 Automatic Lighting Shutoff. Interior lighting in *buildings* larger than 5000 ft^2 shall be controlled with an *automatic control device* to shut off *building* lighting in all spaces. This *automatic control* device shall function on either

(a) a scheduled basis using a time-of-day operated control device that turns lighting off at specific programmed times—an independent program schedule shall be provided for areas of no more than 25,000 ft^2 but not more than one floor—or

(b) an *occupant sensor* that shall turn lighting off within 30 minutes of an occupant leaving a space—or

(c) a signal from another control or alarm system that indicates the area is unoccupied.

Exceptions to 9.4.1.1: The following shall not require an *automatic control device*:

(a) Lighting intended for 24-hour operation

(b) Lighting in spaces where patient care is rendered.

(c) Spaces where an automatic shutoff would endanger the safety or security of the room or building occupant(s).

9.4.1.2 Space Control. Each space enclosed by ceiling-height partitions shall have at least one *control device* to independently *control* the *general lighting* within the space. Each manual device shall be readily accessible and located so the occupants can see the controlled lighting.

(a) A control device shall be installed that automatically turns lighting off within 30 minutes of all occupants leaving a space.

Exception to 9.4.1.2(a): Classrooms, conference/meeting rooms, and employee lunch and break rooms with bi-level switching.

(b) Each *control device* shall be activated either manually by an occupant or automatically by sensing an occupant. Each *control device* shall *control* a maximum of 2500 ft^2 area for a space 10,000 ft^2 or less and a maximum of 10,000 ft^2 area for a space greater than 10,000 ft^2 and be capable of overriding any time-of-day scheduled shutoff *control* for no more than four hours.

Exception to 9.4.1.2(b): Remote location shall be permitted for reasons of safety or security when the remote control device has an indicator pilot light as part of or next to the control device and the light is clearly labeled to identify the controlled lighting.

9.4.1.3 Exterior Lighting Control. Lighting for all exterior applications not exempted in 9.1 shall have automatic controls capable of turning off exterior lighting when sufficient daylight is available or when the lighting is not required during nighttime hours. Lighting not designated for dusk-to-dawn operation shall be controlled by an astronomical time switch. Lighting designated for dusk-to-dawn operation shall be controlled by an astronomical time switch or photosensor. Astronomical time switches shall be capable of retaining programming and the time setting during loss of power for a period of at least 10 hours.

Exception to 9.4.1.3: Lighting for covered vehicle entrances or exits from buildings or parking structures where required for safety, security, or eye adaptation.

9.4.1.4 Additional Control.

(a) *Display/Accent Lighting*—display or accent lighting shall have a separate *control device*.

(b) *Case Lighting*—lighting in cases used for display purposes shall have a separate *control device*.

(c) Hotel and Motel Guest Room Lighting—hotel and motel guest rooms and guest suites shall have at least one master *control device* at the main room entry that *controls* all *permanently installed luminaires* and switched receptacles.

(d) *Task Lighting*—supplemental task lighting, including *permanently installed* undershelf or undercabinet lighting, shall have a *control device* integral to the *luminaires* or be controlled by a wall-mounted *control device* provided the *control device* is readily accessible and located so that the occupant can see the controlled lighting.

(e) *Nonvisual Lighting*—lighting for nonvisual applications, such as plant growth and food warming, shall have a separate *control device*.

(f) *Demonstration Lighting*—lighting equipment that is for sale or for demonstrations in lighting education shall have a separate *control device*.

9.4.2 Tandem Wiring. Luminaires designed for use with one or three linear fluorescent lamps greater than 30 W each shall use two-lamp tandem-wired ballasts in place of single-lamp ballasts when two or more luminaires are in the same space and on the same control device.

Exceptions to 9.4.2:

(a) Recessed luminaires more than 10 ft apart measured center to center.

(b) Surface-mounted or pendant luminaires that are not continuous.

(c) Luminaires using single-lamp high-frequency electronic ballasts.

(d) Luminaires using three-lamp high-frequency electronic or three-lamp electromagnetic ballasts.

(e) Luminaires on emergency circuits.

(f) Luminaires with no available pair.

9.4.3 Exit Signs. Internally illuminated exit signs shall not exceed 5 watts per face.

9.4.4 Exterior Building Grounds Lighting. All exterior building grounds luminaires that operate at greater than 100 watts shall contain lamps having a minimum efficacy of 45 lm/W unless the luminaire is controlled by a motion sensor or qualifies for one of the exceptions under 9.1.1 or 9.4.5.

9.4.5 Exterior Building Lighting Power. The total *exterior lighting power allowance* for all exterior building applications is the sum of the individual lighting power densities permitted in Table 9.4.5 for these applications plus an additional unrestricted allowance of 5% of that sum. Trade-offs are allowed only among exterior lighting applications listed in the Table 9.4.5 "Tradable Surfaces" section.

Exceptions to 9.4.5: Lighting used for the following exterior applications is exempt when equipped with a *control device* independent of the control of the nonexempt lighting:

(a) Specialized signal, directional, and marker lighting associated with transportation.

(b) Advertising signage or directional signage.

(c) Lighting integral to *equipment* or instrumentation and installed by its *manufacturer*.

(d) Lighting for theatrical purposes, including performance, stage, film production, and video production.

(e) Lighting for athletic playing areas.

(f) Temporary lighting.

(g) Lighting for industrial production, material handling, transportation sites, and associated storage areas.

(h) Theme elements in theme/amusement parks.

(i) Lighting used to highlight features of public monuments and registered *historic* landmark structures or *buildings*.

TABLE 9.4.5 Lighting Power Densities for Building Exteriors

Tradable Surfaces (Lighting power densities for uncovered parking areas, building grounds, building entrances and exits, canopies and overhangs and outdoor sales areas may be traded.)	**Uncovered Parking Areas**	
	Parking Lots and drives	**0.15** W/ft^2
	Building Grounds	
	Walkways less than 10 feet wide	**1.0** W/linear foot
	Walkways 10 feet wide or greater Plaza areas Special Feature Areas	**0.2** W/ft^2
	Stairways	**1.0** W/ft^2
	Building Entrances and Exits	
	Main entries	**30** W/linear foot of door width
	Other doors	**20** W/linear foot of door width
	Canopies and Overhangs	
	Canopies (free standing and attached and overhangs)	**1.25** W/ft^2
	Outdoor Sales	
	Open areas (including vehicle sales lots)	**0.5** W/ft^2
	Street frontage for vehicle sales lots in addition to "open area" allowance	**20** W/linear foot
Non-Tradable Surfaces (Lighting power density calculations for the following applications can be used only for the specific application and can- not be traded between surfaces or with other exterior lighting. The following allowances are in addition to any allowance otherwise permitted in the "tradable Surfaces" section of this table.)	**Building Facades**	**0.2** W/ft^2 for each illuminated wall or surface or **5.0** W/linear foot for each illuminated wall or
	Automated teller machines and night depositories	**270** W per location plus **90** W per additional ATM per location
	Entrances and gatehouse inspection stations at guarded facilities	**1.25** W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")
	Loading areas for law enforcement, fire, ambulance and other emergency service vehicles	**0.5** W/ft^2 of uncovered area (covered areas are included in the "Canopies and Overhangs" section of "Tradable Surfaces")
	Drive-up windows at fast food restaurants	**400** W per drive-through
	Parking near 24-hour retail entrances	**800** W per main entry

9.5 Building Area Method Compliance Path

9.5.1 Building Area Method of Calculating Interior Lighting Power Allowance. Use the following steps to determine the interior lighting power allowance by the building area method:

(a) Determine the appropriate building area type from Table 9.5.1 and the allowed lighting power density (watts per unit area) from the building area method column. For building area types not listed, selection of a reasonably equivalent type shall be permitted.

(b) Determine the gross lighted floor area (square feet) of the building area type.

(c) Multiply the gross lighted floor areas of the building area type(s) times the *lighting power density*.

(d) The *interior lighting power allowance* for the building is the sum of the *lighting power allowances* of all building area types. Trade-offs among building area types are permitted provided that the total *installed interior lighting power* does not exceed the *interior lighting power allowance*.

TABLE 9.5.1 Lighting Power Densities Using the Building Area Method

Building Area Type[a]	Lighting Power Density (W/ft^2)
Automotive Facility	0.9
Convention Center	1.2
Court House	1.2
Dining: Bar Lounge/Leisure	1.3
Dining: Cafeteria/Fast Food	1.4
Dining: Family 1.6	1.6
Dormitory	1.0
Exercise Center	1.0
Gymnasium	1.1
Health Care-Clinic	1.0
Hospital	1.2
Hotel	1.0
Library	1.3
Manufacturing Facility	1.3
Motel	1.0
Motion Picture Theater	1.2
Multi-Family	0.7
Museum	1.1
Office	1.0
Parking Garage	0.3
Penitentiary	1.0
Performing Arts Theater	1.6
Police/Fire Station	1.0
Post Office	1.1
Religious Building	1.3
Retail	1.5
School/University	1.2
Sports Arena	1.1
Town Hall	1.1
Transportation	1.0
Warehouse	0.8
Workshop	1.4

[a] In cases where both general building area type and a specific building area type are listed, the specific building area type shall apply.

9.6 Alternative Compliance Path: Space-by-Space Method

9.6.1 Space-by-Space Method of Calculating Interior Lighting Power Allowance. Use the following steps to determine the interior lighting power allowance by the space-by-space method:

(a) Determine the appropriate building type from Table 9.6.1. For building types not listed, selection of a reasonably equivalent type shall be permitted.

(b) For each space enclosed by partitions 80% or greater than ceiling height, determine the gross interior floor area by measuring to the center of the partition wall. Include the floor area of balconies or other projections. Retail spaces do not have to comply with the 80% partition height requirements.

(c) Determine the *interior lighting power allowance* by using the columns designated space-by-space method in Table 9.6.1. Multiply the floor area(s) of the space(s) times the allowed *lighting power density* for the space type that most closely represents the proposed use of the space(s). The product is the *lighting power allowance* for the space(s). For space types not listed, selection of a reasonable equivalent category shall be permitted.

(d) The *interior lighting power allowance* is the sum of *lighting power allowances* of all spaces. Trade-offs among spaces are permitted provided that the total *installed interior lighting power* does not exceed the *interior lighting power allowance*.

TABLE 9.6.1 Lighting Power Densities Using the Space-by-Space Method

Common Space Types[a]	LPD (W/ft^2)	Building Specific Space Types	LPD (W/ft^2)
Office-Enclosed	1.1	Gymnasium/Exercise Center	
Office-Open Plan	1.1	Playing Area	1.4
Conference/Meeting/Multipurpose	1.3	Exercise Area	0.9
Classroom/Lecture/Training	1.4	Courthouse/Police Station/Penitentiary	
For Penitentiary	1.3	Courtroom	1.9
Lobby	1.3	Confinement Cells	0.9
For Hotel	1.1	Judges Chambers	1.3
For Performing Arts Theater	3.3	Fire Stations	
For Motion Picture Theater	1.1	Fire Station Engine Room	0.8
Audience/Seating Area	0.9	Sleeping Quarters	0.3
For Gymnasium	0.4	Post Office—Sorting Area	1.2
For Exercise Center	0.3	Convention Center—Exhibit Space	1.3
For Convention Center	0.7	Library	
For Penitentiary	0.7	Card File and Cataloging	1.1
For Religious Buildings	1.7	Stacks	1.7
For Sports Arena	0.4	Reading Area	1.2
For Performing Arts Theater	2.6	Hospital	
For Motion Picture Theater	1.2	Emergency	2.7
For Transportation	0.5	Recovery	0.8
Atrium—First Three Floors	0.6	Nurse Station	1.0
Atrium—Each Additional Floor	0.2	Exam/Treatment	1.5
Lounge/Recreation	1.2	Pharmacy	1.2
For Hospital	0.8	Patient Room	0.7
Dining Area	0.9	Operating Room	2.2
For Penitentiary	1.3	Nursery	0.6
For Hotel	1.3	Medical Supply	1.4
For Motel	1.2	Physical Therapy	0.9
For Bar Lounge/Leisure Dining	1.4	Radiology	0.4
For Family Dining	2.1	Laundry—Washing	0.6
Food Preparation	1.2	Automotive—Service/Repair	0.7
Laboratory	1.4	Manufacturing	
Restrooms	0.9	Low Bay (<25 ft Floor to Ceiling Height)	1.2
Dressing/Locker/Fitting Room	0.6	High Bay (≥25 ft Floor to Ceiling Height)	1.7
Corridor/Transition	0.5	Detailed Manufacturing	2.1
For Hospital	1.0	Equipment Room	1.2
For Manufacturing Facility	0.5	Control Room	0.5

TABLE 9.6.1 (*continued*) Lighting Power Densities Using the Space-by-Space Method

Stairs—Active	0.6	Hotel/Motel Guest Rooms	1.1
Active Storage	0.8	Dormitory—Living Quarters	1.1
For Hospital	0.9	Museum	
Inactive storage	0.3	General Exhibition	1.0
For Museum	0.8	Restoration	1.7
Electrical/Mechanical	1.5	Bank/Office—Banking Activity Area	1.5
Workshop 1.9		Religious Buildings	
		Worship Pulpit, Choir	2.4
		Fellowship Hall	0.9
		Retail [For accent lighting, see 9.6.3(c)]	
		Sales Area	1.7
		Mall Concourse	1.7
		Sports Arena	
		Ring Sports Area	2.7
		Court Sports Area	2.3
		Indoor Playing Field Area	1.4
		Warehouse	
		Fine Material Storage	1.4
		Medium/Bulky Material Storage	0.9
		Parking Garage—Garage Area	0.2
		Transportation	
		Airport—Concourse	0.6
		Air/Train/Bus—Baggage Area	1.0
		Terminal—Ticket Counter	1.5

[a] In cases where both a common space type and a building specific type are listed, the building specific space type shall apply.

9.6.2 Additional Interior Lighting Power. When using the space-by-space method, an increase in the *interior lighting power allowance* is allowed for specific lighting functions. Additional power shall be allowed only if the specified lighting is installed, shall be used only for the specified *luminaires*, and shall not be used for any other purpose or in any other space.

9.6.3 An increase in the *interior lighting power allowance* is permitted in the following cases:

(a) For spaces in which lighting is specified to be installed in addition to the general lighting for the purpose of decorative appearance, such as chandelier-type luminaries or sconces or for highlighting art or exhibits, provided that the additional lighting power shall not exceed 1.0 W/ft^2 of such spaces.

(b) For spaces in which lighting is specified to be installed to meet the requirements of visual display terminals as the primary viewing task, provided that the additional lighting power shall not exceed 0.35 W/ft^2 of such spaces and that the specified luminaire meets requirements for use in such spaces. Maximum average luminance measured from the vertical in candelas per square foot of not more than 80 cd/ft^2 at 65 degrees, 33 cd/ft^2 at 75 degrees, and 17 cd/ft^2 at 85 to 90 degrees.

(c) For lighting equipment installed in retail spaces that is specifically designed and directed to highlight merchandise, provided that the additional lighting power shall not exceed (1) 1.6 W/ft^2 times the area of specific display or (2) 3.9 W/ft^2 times the area of specific display for valuable merchandise, such as jewelry, fine apparel and accessories, china and silver, art, and similar items, where detailed display and examination of merchandise are important.

9.7 Submittals (Not Used)

9.8 Product Information (Not Used)

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10. OTHER EQUIPMENT

Section 10 – Other Equipment
↓
10.1 – General
↓
10.2 – Definition of Compliance Paths
↓
10.4 – Mandatory Provisions

10.1 General

10.1.1 Scope. This section applies only to the equipment described below.

10.1.1.1 New Buildings. Other equipment installed in new buildings shall comply with the requirements of this section.

10.1.1.2 Additions to Existing Buildings. Other equipment installed in *additions* to *existing buildings* shall comply with the requirements of this section.

10.1.1.3 Alterations to Existing Buildings.

10.1.1.3.1 *Alterations* to other building service equipment or systems shall comply with the requirements of this section applicable to those specific portions of the building and its systems that are being altered.

10.1.1.3.2 Any new equipment subject to the requirements of this section that is installed in conjunction with the *alterations*, as a direct replacement of existing equipment or control devices, shall comply with the specific requirements applicable to that equipment or control devices.

> **Exception to 10.1.1.3:** Compliance shall not be required for the relocation or reuse of existing equipment.

10.2 Compliance Path(s)

10.2.1 Compliance with Section 10 shall be achieved by meeting all requirements of 10.1, General; 10.4, Mandatory Provisions; and 10.8, Product Information.

10.2.2 Projects using the Energy Cost Budget Method (Section 11 of this code), must comply with 10.4, the mandatory provisions of this section, as a portion of that compliance path.

10.3 Simplified/Small Building Option (Not Used)

10.4 Mandatory Provisions

10.4.1 Electric Motors. Electric motors shall comply with the requirements of the Energy Policy Act of 1992 where applicable, as shown in Table 10.8. Motors that are not included in the scope of the Energy Policy Act of 1992 have no performance requirements in this section.

10.5 Prescriptive Compliance Path (Not Used)

10.6 Alternative Compliance Path (Not Used)

10.7 Submittals (Not Used)

10.8 Product Information

TABLE 10.8 Minimum Nominal Efficiency for General Purpose Design A and Design B Motors[a]

	Minimum Nominal Full-Load Efficiency (%)					
	Open Motors			Enclosed Motors		
Number of Poles==>	**2**	**4**	**6**	**2**	**4**	**6**
Synchronous Speed (RPM) ==>	**3600**	**1800**	**1200**	**3600**	**1800**	**1200**
Motor Horsepower						
1	–	82.5	80.0	75.5	82.5	80.0
1.5	82.5	84.0	84.0	82.5	84.0	85.5
2	84.0	84.0	85.5	84.0	84.0	86.5
3	84.0	86.5	85.5	85.5	87.5	87.5
5	85.5	87.5	87.5	87.5	87.5	87.5
7.5	87.5	88.5	88.5	88.5	89.5	89.5
10	88.5	89.5	90.2	89.5	89.5	89.5
15	89.5	91.0	90.2	90.2	91.0	90.2
20	90.2	91.0	91.0	90.2	91.0	90.2
25	91.0	91.7	91.7	91.0	92.4	91.7
30	91.0	92.4	92.4	91.0	92.4	91.7
40	91.7	93.0	93.0	91.7	93.0	93.0
50	92.4	93.0	93.0	92.4	93.0	93.0
60	93.0	93.6	93.6	93.0	93.6	93.6
75	93.0	94.1	93.6	93.0	94.1	93.6
100	93.0	94.1	94.1	93.6	94.5	94.1
125	93.6	94.5	94.1	94.5	94.5	94.1
150	93.6	95.0	94.5	94.5	95.0	95.0
200	94.5	95.0	94.5	95.0	95.0	95.0

[a] Nominal efficiencies shall be established in accordance with NEMA Standard MG1. Design A and Design B are National Electric Manufacturers Association (NEMA) design class designations for fixed frequency small and medium AC squirrel-cage induction motors.

11. ENERGY COST BUDGET METHOD

11.1 General

11.1.1 Energy Cost Budget Method Scope. The building energy cost budget method is an alternative to the prescriptive provisions of this code. It may be employed for evaluating the compliance of all proposed designs, except designs with no mechanical system.

11.1.2 Trade-Offs Limited to Building Permit. When the building permit being sought applies to less than the whole building, only the calculation parameters related to the systems to which the permit applies shall be allowed to vary. Parameters relating to unmodified existing conditions or to future building components shall be identical for both the *energy cost budget* and the *design energy cost* calculations. Future building components shall meet the prescriptive requirements of 5.5, 6.5, 7.5, and either 9.5 or 9.6.

11.1.3 Envelope Limitation. For new buildings or *additions*, the building *energy cost budget* method results shall not be submitted for building permit approval to the *authority having jurisdiction* prior to submittal for approval of the building envelope design.

11.1.4 Compliance. Compliance with Section 11 will be achieved if

(a) all requirements of 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 are met; and

(b) the *design energy cost*, as calculated in 11.3 does not exceed the *energy cost budget*, as calculated by the simulation program described in 11.2; and

(c) the energy *efficiency* level of components specified in the building design meet or exceed the *efficiency* levels used to calculate the *design energy cost*.

Informative Note: *The energy cost budget and the design energy cost calculations are applicable only for determining compliance with this code. They are not predictions of actual energy consumption or costs of the proposed design after construction. Actual experience will differ from these calculations due to variations such as occupancy, building operation and maintenance, weather, energy use not covered by this code, changes in energy rates between design of the building and occupancy, and precision of the calculation tool.*

11.1.5 Documentation Requirements. Compliance shall be documented and submitted to the *authority having jurisdiction*. The information submitted shall include the following:

(a) The *energy cost budget* for the *budget building design* and the *design energy cost* for the *proposed design*.

(b) A list of the energy-related features that are included in the design and on which compliance with the provisions of Section 11 is based. This list shall document all energy features that differ between the models used in the *energy cost budget* and the *design energy cost* calculations.

(c) The input and output report(s) from the *simulation program* including a breakdown of energy usage by at least the following components: lights, internal equipment loads, service water heating equipment, space heating equipment, space cooling and heat rejection equipment, fans, and other HVAC equipment (such as pumps). The output reports shall also show the amount of time any loads are not met by the HVAC system for both the *proposed design* and *budget building design*.

(d) An explanation of any error messages noted in the *simulation program* output.

11.2 Simulation General Requirements

11.2.1 Simulation Program. The *simulation program* shall be a computer-based program for the analysis of energy consumption in buildings (a program such as, but not limited to, DOE-2 or BLAST). The *simulation program* shall include calculation methodologies for the building components being modeled.

Note to Adopting Authority: *The SSPC 90.1 recommends that a compliance shell implementing the rules of the compliance supplement that controls inputs to, and from, output formats from the required computer analysis program be adopted for the purposes of easier use and simpler compliance.*

11.2.1.1 The *simulation program* shall be approved by the *adopting authority* and shall, at a minimum, have the ability to explicitly model all of the following:

(a) a minimum of 1400 hours per year;

(b) hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat setpoints, and HVAC system operation, defined separately for each day of the week and holidays;

(c) thermal mass effects;

(d) ten or more thermal zones;

(e) part-load performance curves for mechanical equipment;

(f) capacity and *efficiency* correction curves for mechanical heating and cooling equipment;

(g) air-side and water-side economizers with integrated control; and

(h) the *budget building design* characteristics specified in 11.5.

11.2.1.2 The *simulation program* shall have the ability to either

(a) directly determine the *design energy cost* and *energy cost budget* or

(b) produce hourly reports of energy use by energy source suitable for determining *the design energy cost* and *energy cost budget* using a separate calculation engine.

11.2.1.3 The *simulation program* shall be capable of performing design load calculations to determine required HVAC equipment capacities and air and water flow rates in accordance with 6.4.2 for both the *proposed design* and *budget building design*.

11.2.1.4 The simulation program shall be tested according to ASHRAE Standard 140 and the results shall be furnished by the software provider.

11.2.2 Climatic Data. The *simulation program* shall perform the simulation using hourly values of climatic data, such as temperature and humidity from representative climatic data, for the city in which the *proposed design* is to be located. For cities or urban regions with several climatic data entries, and for locations where weather data are not available, the designer shall select available weather data that best represent the climate at the construction site. Such selected weather data shall be approved by the *authority having jurisdiction*.

11.2.3 Purchased Energy Rates. Annual energy costs shall be determined using rates for purchased energy, such as electricity, gas, oil, propane, steam, and chilled water, and approved by the *adopting authority*.

Exception to 11.2.3: On-site renewable energy sources or site-recovered energy shall not be considered to be purchased energy and shall not be included in the *design energy cost*. Where on-site renewable or site-recovered sources are used, the *budget building design* shall be based on the energy source used as the backup energy source or electricity if no backup energy source has been specified.

11.2.4 Compliance Calculations. The *design energy cost* and *energy cost budget* shall be calculated using

(a) the same *simulation program*,

(b) the same weather data, and

(c) the same *purchased energy rates*.

11.2.5 Exceptional Calculation Methods. Where no *simulation program* is available that adequately models a design, material, or device, the *authority having jurisdiction* may approve an exceptional calculation method to be used to demonstrate compliance with Section 11. Applications for approval of an exceptional method to include theoretical and empirical information verifying the method's accuracy shall include the following documentation to demonstrate that the exceptional calculation method and results

(a) make no change in any input parameter values specified by this code and the *adopting authority*;

(b) provide input and output documentation that facilitates the enforcement agency's review and meets the formatting and content required by the *adopting authority*; and

(c) are supported by instructions for using the method to demonstrate that the *energy cost budget* and *design energy cost* required by Section 11 are met.

11.3 Calculation of Design Energy Cost and Energy Cost Budget

11.3.1 The simulation model for calculating the design energy cost and the *energy cost budget* shall be developed in accordance with the requirements in Table 11.3.1.

11.3.2 *HVAC Systems*. The *HVAC system* type and related performance parameters for the *budget building* design shall be determined from Figure 11.3.2, the system descriptions in Table 11.3.2A and accompanying notes, and the following rules:

(a) Components and parameters not listed in Figure 11.3.2 and Table 11.3.2A or otherwise specifically addressed in this subsection shall be identical to those in the *proposed design*.

Exception to 11.3.2a: Where there are specific requirements in 6.4 and 6.5, the component *efficiency* in the *budget building design* shall be adjusted to the lowest *efficiency* level allowed by the requirement for that component type.

(b) All HVAC and service water heating equipment in the *budget building* shall be modeled at the minimum *efficiency* levels, both part load and full load, in accordance with 6.4 and 7.4.

(c) Where *efficiency* ratings, such as EER and COP, include fan energy, the descriptor shall be broken down into its components so that supply fan energy can be modeled separately. Supply and return/relief system fans shall be modeled as operating at least whenever the spaces served are occupied except as specifically noted in Table 11.3.2A.

(d) Minimum *outdoor air* ventilation rates shall be the same for both the *budget building design* and proposed building. Heat recovery shall be modeled for the *budget building design* in accordance with 6.5.6.1.

(e) *Budget building* systems as listed in Table 11.3.2A shall have *outdoor air* economizers or water economizers, the same as in the proposed building, in accordance with 6.5.1. The high-limit shutoff shall be in accordance with Table 11.3.2D.

(f) If the *proposed design* system has a preheat coil, the *budget building design's* system shall be modeled with a preheat coil controlled in the same manner.

(g) System design supply air rates for the *budget building design* shall be based on a supply-air-to-room-air temperature difference of 20°F. If return or relief fans are specified in the *proposed design*, the *budget building design* shall also be modeled with the same fan type sized for the budget system supply fan air quantity less the minimum *outdoor air*, or 90% of the supply fan air quantity, whichever is larger.

(h) Fan system *efficiency* (BHP per cfm of supply air including the effect of belt losses but excluding motor and motor drive losses) shall be the same as the *proposed design* or up to the limit prescribed in 6.5.3.1, whichever is smaller. If this limit is reached, each fan shall be proportionally reduced in brake horsepower until the limit is met. Fan electrical power shall then be determined by adjusting the calculated fan HP by the minimum motor *efficiency* prescribed by 10.4 for the appropriate motor size for each fan.

(i) The equipment capacities for the *budget building design* shall be sized proportionally to the capacities in the *proposed design* based on sizing runs; i.e., the ratio between the capacities used in the annual simulations and the capacities determined by the sizing runs shall be the same for both the *proposed design* and *budget building design*. Unmet load hours for the *proposed design* shall not differ from unmet load hours for the *budget building design* by more than 50 hours.

(j) Each *HVAC system* in a *proposed design* is mapped on a one-to-one correspondence with one of eleven *HVAC systems* in the *budget building design*. To determine the budget building system:

Budget System Type

Condenser Cooling Source	Heating System Classification	Single Zone Residential System	Single Zone Non-Residential System	All Other
Water/Ground	Electric Res.	System 5	System 5	System 1
	Heat Pump	System 6	System 6	System 6
	Fossil fuel	System 7	System 7	System 2
Air/None	Electric Res.	System 8	System 9	System 3
	Heat Pump	System 8	System 9	System 3
	Fossil Fuel	System 10	System 11	System 4

Figure 11.3.2 HVAC systems map

1. Enter Figure 11.3.2 at "Water" if the *proposed design* system condenser is water or evaporatively cooled; enter at "Air" if the condenser is air-cooled. Closed-circuit dry-coolers shall be considered air-cooled. Systems utilizing district cooling shall be treated as if the condenser water type were "water." If no mechanical cooling is specified or the mechanical cooling system in the *proposed design* does not require heat rejection, the system shall be treated as if the condenser water type were "Air." For *proposed designs* with ground-source or groundwater-source heat pumps, the budget system shall be water-source heat pump (System 6).

2. Select the path that corresponds to the *proposed design* heat source: electric resistance, heat pump (including air-source and water-source), or fuel-fired. Systems utilizing district heating (steam or hot water) shall be treated as if the heating system type were "Fossil Fuel." Systems with no heating capability shall be treated as if the heating system type were "Fossil Fuel." For systems with mixed fuel heating sources, the system or systems that use the secondary heating source type (the one with the smallest total installed output capacity for the spaces served by the system) shall be modeled identically in the *budget building design* and the primary heating source type shall be used in Figure 11.3.2 to determine budget system type.

3. Select the *budget building design* system category: The system under "Single Zone Residential System" shall be selected if the HVAC system in the proposed design is a single-zone system and serves a residential space. The system under "Single Zone Nonresidential System" shall be selected if the HVAC system in the proposed design is a single-zone system and serves other than residential spaces. The system under "All Other" shall be selected for all other cases.

TABLE 11.3.1 Modeling Requirements for Calculating Design Energy Cost and Energy Cost Budget

No. / Proposed Building Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
1. Design Model	
(a) The simulation model of the *proposed design* shall be consistent with the design documents, including proper accounting of fenestration and opaque envelope types and area; interior lighting power and controls; HVAC system types, sizes, and controls; and service water heating systems and controls. (b) All conditioned spaces in the *proposed design* shall be simulated as being both heated and cooled even if no cooling or heating system is being installed. (c) When the *energy cost budget* method is applied to buildings in which energy-related features have not yet been designed (e.g., a lighting system), those yet-to-be-designed features shall be described in the *proposed design* so that they minimally comply with applicable mandatory and prescriptive requirements from Sections 5 through 10. Where the space classification for a building is not known, the building shall be categorized as an office building.	The *budget building design* shall be developed by modifying the *proposed design* as described in this table. Except as specifically instructed in this table, all building systems and equipment shall be modeled identically in the *budget building design* and *proposed design*.
2. Additions and Alterations	
It is acceptable to demonstrate compliance using building models that exclude parts of the *existing building* provided all of the following conditions are met: (a) Work to be performed under the current permit application in excluded parts of the building shall meet the requirements of Sections 5 through 10. (b) Excluded parts of the building are served by HVAC systems that are entirely separate from those serving parts of the building that are included in the building model. (c) Design space temperature and HVAC system operating setpoints and schedules, on either side of the boundary between included and excluded parts of the building, are identical. (d) If a declining block or similar utility rate is being used in the analysis and the excluded and included parts of the building are on the same utility meter, the rate shall reflect the utility block or rate for the building plus the addition.	Same as Proposed Design
3. Space Use Classification	
The building type or space type classifications shall be chosen in accordance with 9.5.1 or 9.6.1. The user or designer shall specify the space use classifications using either the building type or space type categories but shall not combine the two types of categories within a single permit application. More than one building type category may be used in a building if it is a mixed-use facility.	Same as Proposed Design
4. Schedules	
The schedule types listed in 11.2.1.1 (b) shall be required input. The schedules shall be typical of the proposed building type as determined by the designer and approved by the *authority having jurisdiction*. Required schedules shall be identical for the *proposed design* and *budget building design.*	Same as Proposed Design

Table 11.3.1 (continued) Modeling Requirements for Calculating Design Energy Cost and Energy Cost Budget

No. / Proposed Building Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
5. Building Envelope	
All components of the building envelope in the *proposed design* shall be modeled as shown on architectural drawings or as installed for *existing building* envelopes. *Exceptions*: The following building elements are permitted to differ from architectural drawings. (a) Any envelope assembly that covers less than 5% of the total area of that assembly type (e.g., exterior walls) need not be separately described. If not separately described, the area of an envelope assembly must be added to the area of the adjacent assembly of that same type. (b) Exterior surfaces whose azimuth orientation and tilt differ by no more than 45 degrees and are otherwise the same may be described as either a single surface or by using multipliers. (c) For exterior roofs other than roofs with ventilated attics, the roof surface may be modeled with a reflectance of 0.45 if the reflectance of the proposed design roof is greater than 0.70 and its emittance is greater than 0.75. The reflectance and emittance shall be tested in accordance with 5.4.3.5. All other roof surfaces shall be modeled with a reflectance of 0.3. Manually operated fenestration shading devices such as blinds or shades shall not be modeled. Permanent shading devices Such as fins, overhangs, and light shelves shall be modeled. (d) Manually operated fenestration shading devices such as blinds or shades shall not be modeled. Permanent shading devices such as fins, overhangs, and lightshelves shall be modeled.	The *budget building design* shall have *identical conditioned floor area* and identical exterior dimensions and orientations as the *proposed design*, except as noted in (a), (b), and (c) in this clause. (a) Opaque assemblies such as roof, floors, doors, and walls shall be modeled as having the same heat capacity as the *proposed design* but with the minimum U-factor required in 5.5 for new buildings or *additions* and 5.1.3 for *alterations*. (b) Roof albedo— Low slope roofs shall be modeled using section 5.4.3.5. All other roof surfaces shall be modeled with a reflectivity of 0.3. (c) Fenestration—No shading projections are to be modeled; fenestration shall be assumed to be flush with the exterior wall or roof. If the fenestration area for new buildings or *additions* exceeds the maximum allowed by 5.5.4.2, the area shall be reduced proportionally along each exposure until the limit set in 5.5.4.2 is met. Fenestration U-factor shall be the minimum required for the climate, and the solar heat gain coefficient shall be the maximum allowed for the climate and orientation. The fenestration model for envelope *alterations* shall reflect the limitations on area, U-factor, and solar heat gain coefficient as described in 5.1.3. *Exception*: When trade-offs are made between an *addition* and an *existing building* as described in Exception to 4.2.1.2, the envelope assumptions for the *existing building* in the *budget building design* shall reflect existing conditions prior to any revisions that are part of this permit.
6. Lighting	
Lighting power in the *proposed design* shall be determined as follows: (a) Where a complete lighting system exists, the actual lighting power shall be used in the model. (b) Where a lighting system has been designed, lighting power shall be determined in accordance with either 9.5 or 9.6. (c) Where no lighting exists or is specified, lighting power shall be determined in accordance with the Building Area Method for the Appropriate building type. (d) Lighting system power shall include all lighting system components shown or provided for on plans (including lamps, ballasts, task fixtures, and furniture-mounted fixtures).	Lighting power in the *budget building design* shall be determined using the same categorization procedure (building area or space function) and categories as the *proposed design* with lighting power set equal to the maximum allowed for the corresponding method and category in either 9.5 or 9.6. Power for fixtures not included in the lighting power density calculation shall be modeled identically in the *proposed design* and *budget building design*. Lighting controls shall be the minimum required.
7. Thermal Blocks – HVAC Zones Designed	
Where HVAC zones are defined on HVAC design drawings, each HVAC zone shall be modeled as a separate *thermal block*. *Exception*: Different HVAC zones may be combined to create a single *thermal block* or identical *thermal blocks* to which multipliers are applied provided all of the following conditions are met: (a) The space use classification is the same throughout the *thermal block*. (b) All HVAC zones in the *thermal block* that are adjacent to glazed exterior walls face the same orientation or their orientations are within 45 degrees of each other. (c) All of the zones are served by the same HVAC system or by the same kind of HVAC system.	Same as Proposed Design

Table 11.3.1 (*continued*) Modeling Requirements for Calculating Design Energy Cost and Energy Cost Budget

No.	Proposed Building Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
8. Thermal Blocks – HVAC Zones Not Designed		
	Where the HVAC zones and systems have not yet been designed, *thermal blocks* shall be defined based on similar internal load densities, occupancy, lighting, thermal and space temperature schedules, and in combination with the following guidelines: (a) Separate *thermal blocks* shall be assumed for interior and perimeter spaces. Interior spaces shall be those located more than 15 ft from an exterior wall. Perimeter spaces shall be those located closer than 15 ft from an exterior wall. (b) Separate *thermal blocks* shall be assumed for spaces adjacent to glazed exterior walls; a separate zone shall be provided for each orientation, except orientations that differ by no more than 45 degrees may be considered to be the same orientation. Each zone shall include all floor area that is 15 ft or less from a glazed perimeter wall, except that floor area within 15 ft of glazed perimeter walls having more than one orientation shall be divided proportionately between zones. (c) Separate *thermal blocks* shall be assumed for spaces having floors that are in contact with the ground or exposed to ambient conditions from zones that do not share these features. (d) Separate *thermal blocks* shall be assumed for spaces having exterior ceiling or roof assemblies from zones that do not share these features.	Same as Proposed Design
9. Thermal Blocks - Multifamily Residential Buildings		
	Residential spaces shall be modeled using one *thermal block* per space except that those facing the same orientations may be combined into one thermal block. Corner units and units with roof or floor loads shall only be combined with units sharing these features.	Same as Proposed Design
10. HVAC Systems		
	The HVAC system type and all related performance parameters, such as equipment capacities and efficiencies, in the *proposed design* shall be determined as follows: (a) Where a complete HVAC system exists, the model shall reflect the actual system type using actual component capacities and efficiencies. (b) Where an HVAC system has been designed, the HVAC model shall be consistent with design documents. Mechanical equipment efficiencies shall be adjusted from actual design conditions to the standard rating conditions specified in 6.4.1, if required by the simulation model. (c) Where no heating system exists or no heating system has been specified, the heating system shall be modeled as fossil fuel. The system characteristics shall be identical to the system modeled in the *budget building design*. (d) Where no cooling system exists or no cooling system has been specified, the cooling system shall be modeled as an air-cooled single-zone system, one unit per *thermal block*. The system characteristics shall be identical to the system modeled in the *budget building design*.	The HVAC system type and related performance parameters for the *budget building design* shall be determined from Figure 11.3.2, the system descriptions in Table 11.3.2A and accompanying notes, and in accord with rules specified in 11.3.2 a-j.

Table 11.3.1 (*continued*) Modeling Requirements for Calculating Design Energy Cost and Energy Cost Budget

No. Proposed Building Design (Column A) Design Energy Cost (DEC)	Budget Building Design (Column B) Energy Cost Budget (ECB)
11. Service Hot Water Systems	
The service hot water system type and all related performance parameters, such as equipment capacities and efficiencies, in the *proposed design* shall be determined as follows: (a) Where a complete service hot water system exists, the model shall reflect the actual system type using actual component capacities and efficiencies. (b) Where a service hot water system has been designed, the service hot water model shall be consistent with design documents. (c) Where no service hot water system exists or is specified, no service hot water heating shall be modeled.	The service hot water system type and related performance in the *budget building design* shall be identical to the *proposed design* except where 7.5 applies. In this case the boiler shall be split into a separate space heating boiler and hot water heater with *efficiency* requirements set to the least efficient allowed.
12. Miscellaneous Loads	
Miscellaneous Loads Receptacle, motor, and process loads shall be modeled and estimated based on the building type or space type category and shall be assumed to be identical in the *proposed* and *budget building design*. These loads shall be included in simulations of the building and shall be included when calculating the *energy cost budget* and *design energy cost*. All end-use load components within and associated with the building shall be modeled, unless specifically excluded by Sections 13 and 14 of Table 11.3.1: including, but not limited to, exhaust fans, parking garage ventilation fans, exterior building lighting, swimming pool heaters and pumps, elevators and escalators, refrigeration equipment, and cooking equipment.	Receptacle, motor and process loads shall be modeled and estimated based on the building type or space type category and shall be assumed to be identical in the *proposed* and *budget building design*. These loads shall be included in simulations of the building and shall be included when calculating the *energy cost budget* and *design energy cost*. All end-use load components within and associated with the building shall be modeled, unless specifically excluded by Sections 13 and 14 of Table 11.3.1: including, but not limited to, exhaust fans, parking garage ventilation fans, exterior building lighting, swimming pool heaters and pumps, elevators and escalators, refrigeration equipment, and cooking equipment.
13. Modeling Exceptions	
All elements of the *proposed design* envelope, HVAC, service water heating, lighting, and electrical systems shall be modeled in the *proposed design* in accordance with the requirements of Sections 1 through 12 of Table 11.3.1. Exception: Components and systems in the *proposed design* may be excluded from the simulation model provided: (a) component energy usage does not affect the energy usage of systems and components that are being considered for trade-off; (b) the applicable prescriptive requirements of 5.5, 6.5, 7.5, and either 9.5 or 9.6 applying to the excluded components are met.	None
14. Modeling Limitations to the Simulation Program	
If the simulation program cannot model a component or system included in the *proposed design*, one of the following methods shall be used with the approval of the *authority having jurisdiction*: (a) Ignore the component if the energy impact on the trade-offs being considered is not significant. (b) Model the component substituting a thermodynamically similar component model. (c) Model the HVAC system components or systems using the *budget building design*'s HVAC system in accordance with Section 10 of Table 11.3.1. Whichever method is selected, the component shall be modeled identically for both the *proposed design* and *budget building design* models.	Same as Proposed Design

TABLE 11.3.2A Budget System Descriptions

System No.	System Type	Fan Control	Cooling Type	Heating Type
1	Variable air volume with parallel fan-powered boxes (1)	VAV (4)	Chilled Water (5)	Electric Resistance
2	Variable air volume with reheat (2)	VAV (4)	Chilled Water (5)	Hot Water Fossil Fuel Boiler (6)
3	Packaged variable air volume with parallel fan-powered boxes (1)	VAV (4)	Direct Expansion (3)	Electric Resistance
4	Packaged variable air volume with reheat (2)	VAV (4)	Direct Expansion (3)	Hot Water Fossil Fuel Boiler (6)
5	Two-pipe fan-coil Constant Volume (9)	Constant Volume (9)	Chilled Water (5)	Electric Resistance
6	Water-source heat pump	Volume (9)	Direct Expansion (3)	Electric Heat Pump and Boiler (7)
7	Four-pipe fan coil	Constant Volume (9)	Chilled Water (5)	Hot Water Fossil Fuel Boiler (6)
8	Packaged terminal heat pump	Constant Volume (9)	Direct Expansion (3)	Electric Heat Pump (8)
9	Packaged rooftop heat pump	Constant Volume (9)	Direct Expansion (3)	Electric Heat Pump (8)
10	Packaged terminal air conditioner	Constant Volume (9)	Direct Expansion	Hot Water Fossil Fuel Boiler (6)
11	Packaged rooftop air conditioner	Constant Volume (9)	Direct Expansion	Fossil Fuel Furnace

Notes:

1. **VAV with parallel boxes**: Fans in parallel VAV fan-powered boxes shall be sized for 50% of the peak design flow rate and shall be modeled with 0.35 W/cfm fan power. Minimum volume setpoints for fan-powered boxes shall be equal to the minimum rate for the space required for ventilation consistent with 6.5.2.1 Exception (a) 1. Supply air temperature setpoint shall be constant at the design condition (see 11.3.2 (h)).
2. **VAV with reheat**: Minimum volume setpoints for VAV reheat boxes shall be 0.4 cfm/ft^2 of floor area consistent with 6.5.2.1 Exception (a) 2. Supply air temperature shall be reset based on zone demand from the design temperature difference to a 10°F temperature difference under minimum load conditions. Design air flow rates shall be sized for the reset supply air temperature, i.e., a 10°F temperature difference.
3. **Direct Expansion**: The fuel type for the cooling system shall match that of the cooling system in the *proposed design*.
4. **VAV**: Constant volume can be modeled if the system qualifies for Exception (b) to 6.5.2.1. When the *proposed design* system has a supply, return, or relief fan motor 25 hp or larger, the corresponding fan in the VAV system of the *budget building design* shall be modeled assuming a variable speed drive. For smaller fans, a forward-curved centrifugal fan with inlet vanes shall be modeled. If the *proposed design's* system has a direct digital control system at the zone level, static pressure setpoint reset based on zone requirements in accordance with 6.5.3.2.3 shall be modeled.
5. **Chilled Water**: For systems using purchased chilled water, the chillers are not explicitly modeled and chilled water costs shall be based as determined in 11.2.3. Otherwise, the *budget building design's* chiller plant shall be modeled with chillers having the number as indicated in Table 11.3.2B as a function of budget building chiller plant load and type as indicated in Table 11.3.2C as a function of individual chiller load. Where chiller fuel source is mixed, the system in the *budget building design* shall have chillers with the same fuel types and with capacities having the same proportional capacity as the *proposed design's* chillers for each fuel type. Chilled water supply temperature shall be modeled at 44°F design supply temperature and 56°F return temperature. Piping losses shall not be modeled in either building model. Chilled water supply water temperature shall be reset in accordance with 6.5.4.3. Pump system power for each pumping system shall be the same as the *proposed design*; if the *proposed design* has no chilled water pumps, the *budget building design* pump power shall be 22 W/gpm (equal to a pump operating against a 75 ft head, 65% combined impeller and motor *efficiency*). The chilled water system shall be modeled as primary-only variable flow with flow maintained at the design rate through each chiller using a bypass. Chilled water pumps shall be modeled as riding the pump curve or with variable-speed drives when required in 6.5.4.1. The heat rejection device shall be an axial fan cooling tower with two-speed fans if required in 6.5.5. Condenser water design supply temperature shall be 85°F or 10°F approach to design wet-bulb temperature, whichever is lower, with a design temperature rise of 10°F. The tower shall be controlled to maintain a 70°F leaving water temperature where weather permits, floating up to leaving water temperature at design conditions. Pump system power for each pumping system shall be the same as the *proposed design*; if the *proposed design* has no condenser water pumps, the *budget building design* pump power shall be 19 W/gpm (equal to a pump operating against a 60 ft head, 60% combined impeller and motor *efficiency*). Each chiller shall be modeled with separate condenser water and chilled water pumps interlocked to operate with the associated chiller.
6. **Fossil Fuel Boiler**: For systems using purchased hot water or steam, the boilers are not explicitly modeled and hot water or steam costs shall be based on actual utility rates. Otherwise, the boiler plant shall use the same fuel as the *proposed design* and shall be natural draft. The *budget building design* boiler plant shall be modeled with a single boiler if the *budget building design* plant load is 600,000 Btu/h and less and with two equally sized boilers for plant capacities exceeding 600,000 Btu/h. Boilers shall be staged as required by the load. Hot water supply temperature shall be modeled at 180°F design supply temperature and 130°F return temperature. Piping losses shall not be modeled in either building model. Hot water supply water temperature shall be reset in accordance with 6.5.4.3. Pump system power for each pumping system shall be the same as the *proposed design*; if the *proposed design* has no hot water pumps, the *budget building design* pump power shall be 19 W/gpm (equal to a pump operating against a 60 ft head, 60% combined impeller and motor *efficiency)*. The hot water system shall be modeled as primary-only with continuous variable flow. Hot water pumps shall be modeled as riding the pump curve or with variable speed drives when required by 6.5.4.1.
7. **Electric Heat Pump and Boiler**: Water-source heat pumps shall be connected to a common heat pump water loop controlled to maintain temperatures between 60°F and 90°F. Heat rejection from the loop shall be provided by an axial fan closed-circuit evaporative fluid cooler with two-speed fans if required in 6.5.5.2. Heat addition to the loop shall be provided by a boiler that uses the same fuel as the *proposed design* and shall be natural draft. If no boilers exist in the *proposed design*, the budget building boilers shall be fossil fuel. The budget *building design* boiler plant shall be modeled with a single boiler if the *budget building design* plant load is 600,000 Btu/h or less and with two equally sized boilers for plant capacities exceeding 600,000 Btu/h. Boilers shall be staged as required by the load. Piping losses shall not be modeled in either building model. Pump system power shall be the same as the *proposed design*; if the *proposed design* has no pumps, the *budget building design* pump power shall be 22 W/gpm, which is equal to a pump operating against a 75 foot head, with a 65% combined impeller and motor *efficiency*. Loop flow shall be variable with flow shutoff at each heat pump when its compressor cycles off as required by 6.5.4.4. Loop pumps shall be modeled as riding the pump curve or with variable speed drives when required by 6.5.4.1.
8. **Electric Heat Pump**: Electric air-source heat pumps shall be modeled with electric auxiliary heat. The system shall be controlled with a multi-stage space thermostat and an *outdoor air* thermostat wired to energize auxiliary heat only on the last thermostat stage and when *outdoor air* temperature is less than 40°F.
9. **Constant Volume**: Fans shall be controlled in the same manner as in the *proposed design*; i.e., fan operation whenever the space is occupied or fan operation cycled on calls for heating and cooling. If the fan is modeled as cycling and the fan energy is included in the energy *efficiency* rating of the equipment, fan energy shall not be modeled explicitly.

TABLE 11.3.2B Number of Chillers

Total chiller Plant Capacity	Number of Chillers
≤300 tons	1
>300 tons, < 600 tons	2 sized equally
≥600 tons	2 minimum with chillers added so that no chiller is larger than 800 tons, all sized equally

TABLE 11.3.2C Water Chiller Types

Individual Chiller Plant Capacity	Electric Chiller Type	Fossil Fuel Chiller Type
≤100 tons	Reciprocating	Single-effect absorption, direct fired
>100 tons, <300 tons	Screw	Double-effect absorption, direct fired
≥300 tons	Centrifugal	Double-effect absorption, direct fired

TABLE 11.3.2D Economizer High-Limit Shutoff

Economizer Type	High-Limit Shutoff
Air	Table 6.5.1.1.3B
Water (Integrated)	When its operation will no longer Reduce HVAC system energy
Water (Non-Integrated)	When its operation can no longer provide the cooling load

12. NORMATIVE REFERENCES

Reference	Title
10 CFR Part 430, App N	Uniform Test Method for Measuring the Energy Consumption of Furnaces
42 USC 6831, et seq., Public Law 102-486	Energy Policy Act of 1992
Air Movement and Control Association International, 30 West University Drive, Arlington Heights, IL 60004-1806	
AMCA 500-D-98	Test Methods for Louvers, Dampers, and Shutters
American National Standards Institute, 11 West 42nd Street, New York, NY 10036	
ANSI Z21.10.3-1998	Gas Water Heater, Volume 3, Storage, with Input Ratings above 75,000 Btu/h, Circulating and Instantaneous Water Heaters
ANSI Z21.47-2001	Gas-Fired Central Furnaces (Except Direct Vent and Separated Combustion System Furnaces)
ANSI Z83.8-2002	Gas Unit Heaters and Duct Furnaces
Association of Home Appliance Manufacturers, 20 North Wacker Drive, Chicago, IL 60606	
ANSI/AHAM RAC-1-87	Room Air Conditioners
Air-Conditioning and Refrigeration Institute, 4100 North Fairfax Drive, Suite 200, Arlington, VA 22203	
ARI 210/240-2003	Unitary Air-Conditioning and Heat Pump Equipment
ARI 310/380-2004	Packaged Terminal Air-Conditioners and Heat Pumps
ARI 340/360-2000	Commercial and Industrial Unitary Air-Conditioning and Heat Pump Equipment
ARI 365-2002	Commercial and Industrial Unitary Air-Conditioning Condensing Units
ARI 390-2001	Single Packaged Vertical Air Conditioners and Heat Pumps
ARI 460-2000	Remote Mechanical Draft Air Cooled Refrigerant Condensers
ARI 550/590-98 with Addenda through July 2002	Water-Chilling Packages Using the Vapor Compression Cycle
ARI 560-2000	Absorption Water Chilling and Water Heating Packages
American Society of Heating, Refrigerating and Air-Conditioning Engineers, 1791 Tullie Circle, NE, Atlanta, GA 30329	
ANSI/ASHRAE Standard 62-1999	Ventilation for Acceptable Indoor Air Quality
ANSI/ASHRAE Standard 140-2001	Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs
ANSI/ASHRAE 146-1998	Method of Testing for Rating Pool Heaters
American Society for Testing and Materials, 100 Barr Harbor Dr., West Conshohocken, PA 19428-2959	
ASTM C90-96	Standard Specification for Loadbearing Concrete Masonry Units
ASTM C177-97	Standard Test Method for Steady-State Heat Flux Measurements and Thermal Transmittance Properties by Means of the Guarded-Hot-Plate Apparatus
ASTM C272-91	Test Method for Water Absorption of Core Materials for Structural Sandwich Constructions
ASTM C518-2002	Standard Test Method for Steady-State Thermal Transmittance Properties by Means of the Heat Flow Meter Apparatus
ASTM C835-95 (1999)	Standard Test Method for Total Hemispherical Emittance of Surfaces From 20ºC to 1400ºC
ASTM C1363-97	Standard Test Method for the Thermal Performance of Building Assemblies by Means of a Hot Box Apparatus
ASTM C1371-98	Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers
ASTM E96-95	Test Methods for Water Vapor Transmission of Materials

Reference	Title
ASTM E283-91	Method for Determining Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors Under Specified Pressure Differences Across the Specimen
ASTM E408-71 (1996)	Test Methods for Total Normal Emittance of Surfaces Using Inspection-Meter Techniques
ASTM E903-96	Test Method for Solar Absorptance, Reflectance, and Transmittance of Materials Using Integrating Spheres
ASTM E1175-87 (1996)	Standard Test Method for Determining Solar or Photopic Reflectance, Transmittance, and Absorptance of Materials Using a Large Diameter Integrating Sphere
ASTM E1918-97	Standard Test Method for Measuring Solar Reflectance of Horizontal or Low-Sloped Surfaces in the Field
Cooling Technology Institute, 530 Wells Fargo, Suite 218, Houston, TX 77090; P.O. Box 73383, Houston, TX 77273	
CTI ATC-105(97)	Acceptance Test Code for Water Cooling Towers
CTI STD-201 (96)	Standard for Certification of Water Cooling Tower Thermal Performance
Hydronics Institute, Division of Gama, 35 Russo Place, P.O. Box 218, Berkeley Heights, NJ 07922	
BTS 2000.	Testing Standard Method to Determine Efficiency of Commercial Space Heating Boilers
ISO, 1, rue de Varembe, Case postale 56, CH-1211 Geneve 20, Switzerland	
ISO 13256-1 (1998)	Water-Source Heat Pumps—Testing and Rating for Performance— Part 1: Water-to-Air and Brine-to-Air Heat Pumps
Door and Access Systems Manufacturers Association (DASMA), 1300 Sumner Avenue, Cleveland, OH 44115-2851	
ANSI/DASMA 105-92 (R 1998)	Test Method for Thermal Transmittance and Air Infiltration of Garage Doors
National Electrical Manufacturers Association, 1300 N. 17th Street, Suite 1847, Rosslyn, VA 22209	
ANSI/NEMA MG 1-1993	Motors and Generators
NFPA 96-94	Ventilation Control and Fire Protection of Commercial Cooking Operations
National Fenestration Rating Council, 1300 Spring Street, Suite 500, Silver Springs, MD 20910	
NFRC 100-2001	Procedure for Determining Fenestration Product U-Factors (Second Edition) *Published November 2002*
NFRC 101-2001	Procedure for Determining Thermo-Physical Properties of Materials for Use in NFRC–Approved Software Programs, (First Edition) *Published November 2002*
NFRC 102-2001	Test Procedures for Measuring the Steady-State Thermal Transmittance of Fenestration Systems, (Second Edition) *Published November 2002*
NFRC 200-2001	Procedure for Determining Fenestration Product Solar Heat Gain Coefficients and Visible Transmittance at Normal Incidence (Second Edition) *Published November 2002*
NFRC 201-2001	Interim Standard Test Method for Measuring the Solar Heat Gain Coefficient of Fenestration Systems Using Calorimetry Hot Box Methods, (Second Edition) Published November 2002
NFRC 300-2001	Standard Test Method for Determining the Solar Optical Properties of Glazing Materials and Systems, (Second Edition) Published November 2002
NFRC 400-2001	Procedure for Determining Fenestration Product Air Leakage (Second Edition) Published November 2002

Reference	Title
Underwriters Laboratories, Inc., 333 Pfingsten Rd., Northbrook, IL 60062	
UL 181A-94	Closure Systems for Use with Rigid Air Ducts and Air Connectors
UL 181B-95	Closure Systems for Use with Flexible Air Ducts and Air Connectors
UL 727-94 UL	Standard for Safety—Oil Fired Central Furnaces
UL 731-95 UL	Standard for Safety—Oil-Fired Unit Heaters

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(This is a normative appendix and is part of this code.)

NORMATIVE APPENDIX A

RATED R-VALUE OF INSULATION AND ASSEMBLY U-FACTOR, C-FACTOR, AND F-FACTOR DETERMINATIONS

A1 General

A1.1 Pre-Calculated Assembly U-Factors, C-Factors, F-Factors, or Heat Capacities. The *U-factors*, *C-factors*, *F-factors*, and *heat capacities* for typical construction assemblies are included in A2 through A8. These values shall be used for all calculations unless otherwise allowed by A1.2. Interpolation between values in a particular table in Appendix A is allowed for *rated R-values of insulation*, including insulated sheathing. Extrapolation beyond values in a table in Appendix A is not allowed.

A1.2 Applicant-Determined Assembly U-Factors, C-Factors, F-Factors, or Heat Capacities. If the *building official* determines that the proposed construction assembly is not adequately represented in A2 through A8, the applicant shall determine appropriate values for the assembly using the assumptions in A9. An assembly is deemed to be adequately represented if

(a) the interior structure, hereafter referred to as the base assembly, for the *class of construction* is the same as described in A2 through A8 and

(b) changes in exterior or interior surface *building materials* added to the base assembly do not increase or decrease the R-value by more than 2 from that indicated in the descriptions in A2 through A8. Insulation, including insulated sheathing, is not considered a *building material*.

A2 Roofs

A2.1 General. The buffering effect of suspended ceilings or attic spaces shall not be included in *U-factor* calculations.

A2.2 Roofs with Insulation Entirely Above Deck.

A2.2.1 General. For the purpose of A1.2, the base assembly is *continuous insulation* over a structural deck. The *U-factor* includes R-0.17 for exterior air film, R-0 for metal deck, and R-0.61 for interior air film heat flow up. Added insulation is continuous and uninterrupted by framing. The framing factor is zero.

A2.2.2 Rated R-Value of insulation. For *roofs with insulation entirely above deck*, the rated *R-value of insulation* is for *continuous insulation*.

Exception to A2.2.2: Interruptions for framing and pads for mechanical equipment are permitted with a combined total area not exceeding one percent of the total opaque assembly area.

A2.2.3 U-factor. *U-factors* for *roofs with insulation entirely above deck* shall be taken from Table A2.2. It is not acceptable to use these *U-factors* if the insulation is not entirely above deck or not continuous.

TABLE A2.2 Assembly U-Factors for Roofs with Insulation Entirely Above Deck

Rated R-Value of Insulation Alone	Overall U-Factor for Entire Assembly
R-0	U-1.282
R-1	U-0.562
R-2	U-0.360
R-3	U-0.265
R-4	U-0.209
R-5	U-0.173
R-6	U-0.147
R-7	U-0.129
R-8	U-0.114
R-9	U-0.102
R-10	U-0.093
R-11	U-0.085
R-12	U-0.078
R-13	U-0.073
R-14	U-0.068
R-15	U-0.063
R-16	U-0.060
R-17	U-0.056
R-18	U-0.053
R-19	U-0.051
R-20	U-0.048
R-21	U-0.046
R-22	U-0.044
R-23	U-0.042
R-24	U-0.040
R-25	U-0.039
R-26	U-0.037
R-27	U-0.036
R-28	U-0.035
R-29	U-0.034
R-30	U-0.032
R-35	U-0.028
R-40	U-0.025
R-45	U-0.022
R-50	U-0.020
R-55	U-0.018
R-60	U-0.016

A2.3 Metal Building Roofs.

A2.3.1 General: For the purpose of A1.2, the base assembly is a *roof* where the insulation is draped over the steel structure (purlins) and then compressed when the metal spanning members are attached to the steel structure (purlins). Additional assemblies include *continuous insulation*, uncompressed and uninterrupted by framing.

A2.3.2 Rated R-Value of insulation.

A2.3.2.1 The first *rated R-value of insulation* is for insulation draped over purlins and then compressed when the metal spanning members are attached, or for insulation hung between the purlins, provided there is a minimum 1 in. thermal break between the purlins and the metal spanning members.

A2.3.2.2 For double-layer installations, the second *rated R-value of insulation* is for insulation installed parallel to the purlins.

A2.3.2.3 For continuous insulation (e.g., insulation boards), it is assumed that the insulation boards are installed below the purlins and are uninterrupted by framing members. Insulation exposed to the *conditioned space* or *semiheated space* shall have a facing, and all insulation seams shall be continuously sealed to provide a continuous air barrier.

A2.3.3 U-factor. *U-factors* for *metal building roofs* shall be taken from Table A2.3 It is not acceptable to use the *continuous insulation U-factors* if additional insulated sheathing is not continuous.

TABLE A2.3 Assembly U-Factors for Metal Building Roofs

Insulation System	Rated R-Value of Insulation	Total Rated R-Value of Insulation	Overall U-Factor for Entire Base Roof Assembly	Overall U-Factor for Assembly of Base Roof Plus Continuous Insulation (uninterrupted by framing) Rated R-Value of Continuous Insulation					
				R-5	R-11.2	R-16.8	R-22.4	R-28.0	R-33.6
Standing Seam Roofs with Thermal Blocks									
Single Layer	None	0	**1.280**	0.162	0.087	0.059	0.045	0.036	0.030
	R-6	6	**0.167**	0.086	0.058	0.044	0.035	0.029	0.025
	R-10	10	**0.097**	0.063	0.046	0.037	0.031	0.026	0.023
	R-11	11	**0.092**	0.061	0.045	0.036	0.030	0.026	0.022
	R-13	13	**0.083**	0.057	0.043	0.035	0.029	0.025	0.022
	R-16	16	**0.072**	0.051	0.040	0.033	0.028	0.024	0.021
	R-19	19	**0.065**	0.048	0.038	0.031	0.026	0.023	0.020
Double Layer	R-10 + R-10	20	**0.063**	0.047	0.037	0.031	0.026	0.023	0.020
	R-10 + R-11	21	**0.061**	0.045	0.036	0.030	0.026	0.023	0.020
	R-11 + R-11	22	**0.060**	0.045	0.036	0.030	0.026	0.022	0.020
	R-10 + R-13	23	**0.058**	0.044	0.035	0.029	0.025	0.022	0.020
	R-11 + R-13	24	**0.057**	0.043	0.035	0.029	0.025	0.022	0.020
	R-13 + R-13	26	**0.055**	0.042	0.034	0.029	0.025	0.022	0.019
	R-10 + R-19	29	**0.052**	0.040	0.033	0.028	0.024	0.021	0.019
	R-11 + R-19	30	**0.051**	0.040	0.032	0.027	0.024	0.021	0.019
	R-13 + R-19	32	**0.049**	0.038	0.032	0.027	0.023	0.021	0.019
	R-16 +R-19	35	**0.047**	0.037	0.031	0.026	0.023	0.021	0.018
	R-19 + R-19	38	**0.046**	0.037	0.030	0.026	0.023	0.020	0.018
(Multiple R-values are listed in order from inside to outside)									
Screw Down Roofs									
	R-10	10	**0.153**	0.082	0.056	0.043	0.035	0.029	0.025
	R-11	11	**0.139**	0.078	0.054	0.042	0.034	0.028	0.025
	R-13	13	**0.130**	0.075	0.053	0.041	0.033	0.028	0.024
Filled Cavity with Thermal Blocks									
	R-19 + R-10	29	**0.041**	0.033	0.028	0.024	0.021	0.020	0.017
(Multiple R-values are listed in order from inside to outside)									

TABLE A2.4 Assembly U-Factors for Attic Roofs with Wood Joists

Rated R-Value of Insulation Alone	Overall U-Factor for Entire Assembly
Wood-framed attic, standard framing	
None	0.613
R-11	0.091
R-13	0.081
R-19	0.053
R-30	0.034
R-38	0.027
R-49	0.021
R-60	0.017
R-71	0.015
R-82	0.013
R-93	0.011
R-104	0.010
R-115	0.009
R-126	0.008
Wood-framed attic, advanced framing	
None	0.613
R-11	0.088
R-13	0.078
R-19	0.051
R-30	0.032
R-38	0.026
R-49	0.020
R-60	0.016
R-71	0.014
R-82	0.012
R-93	0.011
R-104	0.010
R-115	0.009
R-126	0.008
Wood joists, single-rafter roof	
None	0.417
R-11	0.088
R-13	0.078
R-15	0.071
R-19	0.055
R-21	0.052
R-25	0.043
R-30	0.036
R-38	0.028

A2.4 Attic Roofs with Wood Joists

A2.4.1 General. For the purpose of A1.2, the base *attic roof* assembly is a *roof* with a nominal 4 in. deep wood as the lower chord of a roof truss or ceiling joist. The ceiling is attached directly to the lower chord of the truss and the attic space above is ventilated. Insulation is located directly on top of the ceiling, first filling the cavities between the wood and then later covering both the wood and cavity areas. No credit is given for roofing materials. The *single-rafter roof* is similar to the base *attic roof*, with the key difference being that there is a single, deep rafter to which both the *roof* and the ceiling are attached. The heat flow path through the rafter is calculated to be the same depth as the insulation. The *U-factor* includes R-0.46 for semi-exterior air film, R-0.56 for 0.625 in. gypsum board, and R-0.61 for interior air film heat flow up. *U-factors* are provided for the following configurations:

(a) *Attic roof*, *standard framing*: insulation is tapered around the perimeter with resultant decrease in thermal resistance. Weighting factors are 85% full-depth insulation, 5% half-depth insulation, and 10% joists.

(b) *Attic roof*, *advanced framing*: full and even depth of insulation extending to the outside edge of exterior walls. Weighting factors are 90% full-depth insulation and 10% joists.

(c) *Single-rafter roof*: an attic *roof* where the roof sheathing and ceiling are attached to the same rafter. Weighting factors are 90% full-depth insulation and 10% joists.

A2.4.2 Rated R-Value of Insulation.

A2.4.2.1 For *attics* and *other roofs*, the *rated R-value of insulation* is for insulation installed both inside and outside the roof or entirely inside the roof cavity.

A2.4.2.2 Occasional interruption by framing members is allowed but requires that the framing members be covered with insulation when the depth of the insulation exceeds the depth of the framing cavity.

A2.4.2.3 Insulation in such roofs shall be permitted to be tapered at the eaves where the building structure does not allow full depth.

A2.4.2.4 For *single-rafter roofs*, the requirement is the lesser of the values for *attics* and *other roofs* and those listed in Table A2.4.2.

TABLE A2.4.2 Single-Rafter Roofs

Climate Zone	Minimum Insulation R-Value or Maximum Assembly U-Factor		
	Wood Rafter Depth, *d* (actual)		
	$d \le 8$ in.	$8 < d \le 10$ in	$10 < d \le 12$ in
1-7	R-19 U-0.055	R-30 U-0.036	R-38 U-0.028
8	R-21 U-0.052	R-30 U-0.036	R-38 U-0.028

A2.4.3 U-factors for Attic Roofs with Wood Joists. *U-factors* for *attic roofs* with wood joists shall be taken from Table A2.4. It is not acceptable to use these *U-factors* if the framing is not wood. For *attic roofs* with steel joists, see A2.5.

A2.5 Attic Roofs with Steel Joists.

A2.5.1 General: For the purpose of A1.2, the base assembly is a roof supported by steel joists with insulation between the joists. The assembly represents a *roof* in many ways similar to a *roof with insulation entirely above deck* and a *metal building roof*. It is distinguished from the *metal building roof* category in that there is no metal exposed to the exterior. It is distinguished from the *roof with insulation entirely above deck* in that the insulation is located below the deck and is interrupted by metal trusses that provide thermal bypasses to the insulation. The *U-factor* includes R-0.17 for exterior air film, R-0 for metal deck, and R-0.61 for interior air film heat flow up. The performance of the insulation/framing layer is calculated using the values in Table A9.2A.

A2.5.2 *U-factors* for *attic roofs* with steel joists shall be taken from Table A2.5. It is acceptable to use these *U-factors* for any *attic roof* with steel joists.

TABLE A2.5 Assembly U-Factors for Attic Roofs with Steel Joists (4.0 ft on center)

Rated R-Value of Insulation Area	Overall U-Factor for Entire Assembly
R-0	U-1.282
R-4	U-0.215
R-5	U-0.179
R-8	U-0.120
R-10	U-0.100
R-11	U-0.093
R-12	U-0.086
R-13	U-0.080
R-15	U-0.072
R-16	U-0.068
R-19	U-0.058
R-20	U-0.056
R-21	U-0.054
R-24	U-0.049
R-25	U-0.048
R-30	U-0.041
R-35	U-0.037
R-38	U-0.035
R-40	U-0.033
R-45	U-0.031
R-50	U-0.028
R-55	U-0.027

A3 Above-Grade Walls

A3.1 Mass Wall

A3.1.1 General. For the purpose of A1.2, the base assembly is a masonry or concrete *wall*. *Continuous insulation* is installed on the interior, exterior, or within the masonry units, or it is installed on the interior or exterior of the concrete. The *U-factor* includes R-0.17 for exterior air film and R-0.68 for interior air film, vertical surfaces. For insulated walls, the U-factor also includes R-0.45 for 0.5 in. gypsum board. *U-factors* are provided for the following configurations:

(a) Concrete *wall*: 8 in. normal weight concrete wall with a density of 145 lb/ft^3.

(b) Solid grouted concrete block *wall*: 8 in. medium weight ASTM C90 concrete block with a density of 115 lb/ft^3 and solid grouted cores.

(c) Partially grouted concrete block *wall*: 8 in. medium weight ASTM C90 concrete block with a density of 115 lb/ft^3 having reinforcing steel every 32 in. vertically and every 48 in. horizontally, with cores grouted in those areas only. Other cores are filled with insulating material only if there is no other insulation.

A3.1.2 Mass Wall Rated R-value of Insulation.

A3.1.2.1 Mass wall heat capacity shall be determined from Table A3.1B or A3.1C.

A3.1.2.2 The *rated R-value of insulation* is for *continuous insulation* uninterrupted by framing other than 20 gauge 1 in. metal clips spaced no closer than 24 in. on center horizontally and 16 in. on center vertically.

A3.1.2.3 Where other framing, including metal and wood studs, is used, compliance shall be based on the maximum assembly *U-factor*.

A3.1.2.4 Where *rated R-value of insulation* is used for concrete sandwich panels, the insulation shall be continuous throughout the entire panel.

A3.1.3 Mass Wall U-factor.

A3.1.3.1 *U-factors* for *mass walls* shall be taken from Table A3.1A or determined by the procedure in this subsection. It is acceptable to use the *U-factors* in Table A3.1A for all *mass walls*, provided that the grouting is equal to or less than that specified. *Heat capacity* for *mass walls* shall be taken from Table A3.1B or A3.1C.

> **Exception to A3.1.3.1:** For *mass walls*, where the requirement in Table 5.5-2 is for a maximum assembly U-0.151 followed by footnote "a," ASTM C90 concrete block walls, ungrouted or partially grouted at 32 in. or less on center vertically and 48 in. or less on center horizontally, shall have ungrouted cores filled with material having a maximum thermal conductivity of 0.44 Btu·in./ h·ft^2·°F. Other *mass walls* with integral insulation shall meet the criteria when their *U-factors* are equal to or less than those for the appropriate thickness and density in the "Partly Grouted Cells Insulated" column of Table A3.1C.

A3.1.3.2 Determination of Mass Wall U-Factors. If not taken from Table A3.1A, *mass wall U-factors* shall be determined from Tables A3.1B, A3.1C, and A3.1D using the following procedure.

1. If the *mass wall* is uninsulated or only the cells are insulated:

   (a) For concrete *walls*, determine the *U-factor* from Table A3.1B based on the concrete density and *wall* thickness.

   (b) For concrete block *walls*, determine the *U-factor* from Table A3.1C based on the block size, concrete density, degree of grouting in the cells, and whether the cells are insulated.

2. If the *mass wall* has additional insulation:

   (a) For concrete *walls*, determine the R_u from Table A3.1B based on the concrete density and *wall* thickness. Next, determine the effective R-value for the insulation/ framing layer from Table A3.1D based on the *rated R-value of insulation* installed, the thickness of the insulation, and whether it is installed between wood or metal framing or with no framing. Then, determine the *U-factor* by adding the R_u and the effective R-value together and taking the inverse of the total.

(b) For concrete block *walls*, determine the R_u from Table A3.1C based on the block size, concrete density, degree of grouting in the cells, and whether the cells are insulated. Next, determine the effective R-value for the insulation/framing layer from Table A3.1D based on the *rated R-value of insulation* installed, the thickness of the insulation, and whether it is installed between wood or metal framing or with no framing. Then, determine the *U-factor* by adding the R_u and the effective R-value together and taking the inverse of the total.

A3.2 Metal Building Walls.

A3.2.1 General. For the purpose of A1.2, the base assembly is a *wall* where the insulation is compressed between metal wall panels and the metal structure. Additional assemblies include *continuous insulation*, uncompressed and uninterrupted by framing.

A3.2.2 Rated R-value of Insulation for Metal Building Walls.

A3.2.2.1 The first *rated R-Value of insulation* is for insulation compressed between metal wall panels and the steel structure.

A3.2.2.2 For double-layer installations, the second *rated R-value of insulation* is for insulation installed from the inside, covering the girts.

A3.2.2.3 For continuous insulation (e.g., insulation boards) it is assumed that the insulation boards are installed on the inside of the girts and uninterrupted by the framing members.

A3.2.2.4 Insulation exposed to the *conditioned space* or *semiheated space* shall have a facing, and all insulation seams shall be continuously sealed to provide a continuous air barrier.

A3.2.3 U-Factors for Metal Building Walls. *U-factors* for metal building walls shall be taken from Table A3.2. It is not acceptable to use these *U-factors* if additional insulation is not continuous.

TABLE A3.1A Assembly U-Factors for Above-Grade Concrete Walls and Masonry Walls

Framing Type and Depth	Rated R-Value of Insulation Alone	Assembly U-Factors for 8 in. Normal Weight 145 lb/ft^3 Solid Concrete Walls Solid	Assembly U-Factors for 8 in. Medium Weight 115 lb/ft^3 Concrete Block Walls: Solid Grouted	Assembly U-Factors for 8 in. Medium Weight 115 Concrete Block Walls: Partially Grouted (cores uninsulated except where specified)
	R-0	**U-0.740**	**U-0.580**	**U-0.480**
No Framing	**Ungrouted Cores Filled with Loose-Fill Insulation**	**N.A.**	**N.A.**	**U-0.350**
Continuous metal framing at 24 in. on center horizontally				
3.5 in.	R-11.0	U-0.168	U-0.158	U-0.149
3.5 in.	R-13.0	U-0.161	U-0.152	U-0.144
3.5 in.	R-15.0	U-0.155	U-0.147	U-0.140
4.5 in.	R17.1	U-0.133	U-0.126	U-0.121
4.5 in.	R-22.5	U-0.124	U-0.119	U-0.114
4.5 in.	R-25.2	U-0.122	U-0.116	U-0.112
5.0 in.	R-19.0	U-0.122	U-0.117	U-0.112
5.0 in.	R-25.0	U-0.115	U-0.110	U-0.106
5.0 in.	R-28.0	U-0.112	U-0.107	U-0.103
5.5 in.	R-19.0	U-0.118	U-0.113	U-0.109
5.5 in.	R-20.9	U-0.114	U-0.109	U-0.105
5.5 in.	R-21.0	U-0.113	U-0.109	U-0.105
5.5 in.	R-27.5	U-0.106	U-0.102	U-0.099
5.5 in.	R-30.8	U-0.104	U-0.100	U-0.096
6.0 in.	R-22.8	U-0.106	U-0.102	U-0.098
6.0 in.	R-30.0	U-0.099	U-0.095	U-0.092
6.0 in.	R-33.6	U-0.096	U-0.093	U-0.090
6.5 in.	R-24.7	U-0.099	U-0.096	U-0.092
7.0 in.	R-26.6	U-0.093	U-0.090	U-0.087
7.5 in.	R-28.5	U-0.088	U-0.085	U-0.083
8.0 in.	R-30.4	U-0.083	U-0.081	U-0.079
1 in. metal clips at 24 in. on center horizontally and 16 in. vertically				
1.0 in.	R-3.8	U-0.210	U-0.195	U-0.182
1.0 in.	R-5.0	U-0.184	U-0.172	U-0.162
1.0 in.	R-5.6	U-0.174	U-0.163	U-0.154
1.5 in.	R-5.7	U-0.160	U-0.151	U-0.143
1.5 in.	R-7.5	U-0.138	U-0.131	U-0.125
1.5 in.	R-8.4	U-0.129	U-0.123	U-0.118
2.0 in.	R-7.6	U-0.129	U-0.123	U-0.118
2.0 in.	R-10.0	U-0.110	U-0.106	U-0.102
2.0 in.	R-11.2	U-0.103	U-0.099	U-0.096
2.5 in.	R-9.5	U-0.109	U-0.104	U-0.101
2.5 in.	R-12.5	U-0.092	U-0.089	U-0.086
2.5 in.	R-14.0	U-0.086	U-0.083	U-0.080
3.0 in.	R-11.4	U-0.094	U-0.090	U-0.088
3.0 in.	R-15.0	U-0.078	U-0.076	U-0.074
3.0 in.	R-16.8	U-0.073	U-0.071	U-0.069
3.5 in.	R-13.3	U-0.082	U-0.080	U-0.077
3.5 in.	R-17.5	U-0.069	U-0.067	U-0.065
3.5 in.	R-19.6	U-0.064	U-0.062	U-0.061
4.0 in.	R-15.2	U-0.073	U-0.071	U-0.070
4.0 in.	R-20.0	U-0.061	U-0.060	U-0.058
4.0 in.	R-22.4	U-0.057	U-0.056	U-0.054
5.0 in.	R-28.0	U-0.046	U-0.046	U-0.045
6.0 in.	R-33.6	U-0.039	U-0.039	U-0.038
7.0 in.	R-39.2	U-0.034	U-0.034	U-0.033
8.0 in.	R-44.8	U-0.030	U-0.030	U-0.029
9.0 in.	R-50.4	U-0.027	U-0.027	U-0.026
10.0 in.	R-56.0	U-0.024	U-0.024	U-0.024
11.0 in.	R-61.6	U-0.022	U-0.022	U-0.022

TABLE A3.1A *(continued)* Assembly U-Factors for Above-Grade Concrete Walls and Masonry Walls

Framing Type and Depth	Rated R-Value of Insulation Alone	Assembly U-Factors for 8 in. Normal Weight 145 lb/ft^3 Solid Concrete Walls Solid	Assembly U-Factors for 8 in. Medium Weight 115 lb/ft^3 Concrete Block Walls: Solid Grouted	Assembly U-Factors for 8 in. Medium Weight 115 Concrete Block Walls: Partially Grouted (cores uninsulated except where specified)
Continuous insulation uninterrupted by framing				
No Framing	R-1.0	U-0.425	U-0.367	U-0.324
No Framing	R-2.0	U-0.298	U-0.269	U-0.245
No Framing	R-3.0	U-0.230	U-0.212	U-0.197
No Framing	R-4.0	U-0.187	U-0.175	U-0.164
No Framing	R-5.0	U-0.157	U-0.149	U-0.141
No Framing	R-6.0	U-0.136	U-0.129	U-0.124
No Framing	R-7.0	U-0.120	U-0.115	U-0.110
No Framing	R-8.0	U-0.107	U-0.103	U-0.099
No Framing	R-9.0	U-0.097	U-0.093	U-0.090
No Framing	R-10.0	U-0.088	U-0.085	U-0.083
No Framing	R-11.0	U-0.081	U-0.079	U-0.076
No Framing	R-12.0	U-0.075	U-0.073	U-0.071
No Framing	R-13.0	U-0.070	U-0.068	U-0.066
No Framing	R-14.0	U-0.065	U-0.064	U-0.062
No Framing	R-15.0	U-0.061	U-0.060	U-0.059
No Framing	R-16.0	U-0.058	U-0.056	U-0.055
No Framing	R-17.0	U-0.054	U-0.053	U-0.052
No Framing	R-18.0	U-0.052	U-0.051	U-0.050
No Framing	R-19.0	U-0.049	U-0.048	U-0.047
No Framing	R-20.0	U-0.047	U-0.046	U-0.045
No Framing	R-21.0	U-0.045	U-0.044	U-0.043
No Framing	R-22.0	U-0.043	U-0.042	U-0.042
No Framing	R-23.0	U-0.041	U-0.040	U-0.040
No Framing	R-24.0	U-0.039	U-0.039	U-0.038
No Framing	R-25.0	U-0.038	U-0.037	U-0.037
No Framing	R-30.0	U-0.032	U-0.032	U-0.031
No Framing	R-35.0	U-0.028	U-0.027	U-0.027
No Framing	R-40.0	U-0.024	U-0.024	U-0.024
No Framing	R-45.0	U-0.022	U-0.021	U-0.021
No Framing	R-50.0	U-0.019	U-0.019	U-0.019
No Framing	R-55.0	U-0.018	U-.0.018	U-0.018
No Framing	R-60.00	U-0.0016	U-0.016	U-0.016

TABLE A3.1B Assembly U-Factors, C-Factors, R_u, R_c, and Heat Capacity for Concrete

Density In lb/ft³	Properties	Thickness in inches 3	4	5	6	7	8	9	10	11	12
20	U-factor	0.22	0.17	0.14	0.12	0.10	0.09	0.08	0.07	0.07	0.06
	C-factor	0.27	0.20	0.16	0.13	0.11	0.10	0.09	0.08	0.07	0.07
	R_u	4.60	5.85	7.10	8.35	9.60	10.85	12.10	13.35	14.60	15.85
	R_c	3.75	5.00	6.25	7.50	8.75	10.00	11.25	12.50	13.75	15.00
	HC	1.0	1.3	1.7	2.0	2.3	2.7	3.0	3.3	3.7	4.0
30	U-factor	0.28	0.22	0.19	0.16	0.14	0.12	0.11	0.10	0.09	0.09
	C-factor	0.37	0.28	0.22	0.18	0.16	0.14	0.12	0.11	0.10	0.09
	R_u	3.58	4.49	5.40	6.30	7.21	8.12	9.03	9.94	10.85	11.76
	R_c	2.73	3.64	4.55	5.45	6.36	7.27	8.18	9.09	10.00	10.91
	HC	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
40	U-factor	0.33	0.27	0.23	0.19	0.17	0.15	0.14	0.13	0.11	0.11
	C-factor	0.47	0.35	0.28	0.23	0.20	0.18	0.16	0.14	0.13	0.12
	R_u	2.99	3.71	4.42	5.14	5.85	6.56	7.28	7.99	8.71	9.42
	R_c	2.14	2.86	3.57	4.29	5.00	5.71	6.43	7.14	7.86	8.57
	HC	2.0	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.3	8.0
50	U-factor	0.38	0.31	0.26	0.23	0.20	0.18	0.16	0.15	0.14	0.13
	C-factor	0.57	0.43	0.34	0.28	0.24	0.21	0.19	0.17	0.15	0.14
	R_u	2.61	3.20	3.79	4.38	4.97	5.56	6.14	6.73	7.32	7.91
	R_c	1.76	2.35	2.94	3.53	4.12	4.71	5.29	5.88	6.47	7.06
	HC	2.5	3.3	4.2	5.0	5.8	6.7	7.5	8.3	9.2	10.0
85	U-factor	0.65	0.56	0.50	0.44	0.40	0.37	0.34	0.31	0.29	0.27
	C-factor	1.43	1.08	0.86	0.71	0.61	0.54	0.48	0.43	0.39	0.36
	R_u	1.55	1.78	2.01	2.25	2.48	2.71	2.94	3.18	3.41	3.64
	R_c	0.70	0.93	1.16	1.40	1.63	1.86	2.09	2.33	2.56	2.79
	HC	4.3	5.7	7.1	8.5	9.9	11.3	12.8	14.2	15.6	17.0
95	U-factor	0.72	0.64	0.57	0.52	0.48	0.44	0.41	0.38	0.36	0.33
	C-factor	1.85	1.41	1.12	0.93	0.80	0.70	0.62	0.56	0.51	0.47
	R_u	1.39	1.56	1.74	1.92	2.10	2.28	2.46	2.64	2.81	2.99
	R_c	0.54	0.71	0.89	1.07	1.25	1.43	1.61	1.79	1.96	2.14
	HC	4.8	6.3	7.9	9.5	11.1	12.7	14.3	15.8	17.4	19.0
105	U-factor	0.79	0.71	0.65	0.59	0.54	0.51	0.47	0.44	0.42	0.39
	C-factor	2.38	1.79	1.43	1.18	1.01	0.88	0.79	0.71	0.65	0.59
	R_u	1.27	1.41	1.56	1.70	1.84	1.98	2.12	2.26	2.40	2.54
	R_c	0.42	0.56	0.70	0.85	0.99	1.13	1.27	1.41	1.55	1.69
	HC	5.3	7.0	8.8	10.5	12.3	14.0	15.8	17.5	19.3	21.0
115	U-factor	0.84	0.77	0.70	0.65	0.61	0.57	0.53	0.50	0.48	0.45
	C-factor	2.94	2.22	1.75	1.47	1.25	1.10	0.98	0.88	0.80	0.74
	R_u	1.19	1.30	1.42	1.53	1.65	1.76	1.87	1.99	2.10	2.21
	R_c	0.34	0.45	0.57	0.68	0.80	0.91	1.02	1.14	1.25	1.36
	HC	5.8	7.7	9.6	11.5	13.4	15.3	17.3	19.2	21.1	23.0
125	U-factor	0.88	0.82	0.76	0.71	0.67	0.63	0.60	0.56	0.53	0.51
	C-factor	3.57	2.70	2.17	1.79	1.54	1.35	1.20	1.03	0.98	0.90
	R_u	1.13	1.22	1.31	1.41	1.50	1.59	1.68	1.78	1.87	1.96
	R_c	0.28	0.37	0.46	0.56	0.65	0.74	0.83	0.93	1.02	1.11
	HC	6.3	8.3	10.4	12.5	14.6	16.7	18.8	20.8	22.9	25.0
135	U-factor	0.93	0.87	0.82	0.77	0.73	0.69	0.66	0.63	0.60	0.57
	C-factor	4.55	3.33	2.70	2.22	1.92	1.67	1.49	1.33	1.22	1.11
	R_u	1.07	1.15	1.22	1.30	1.37	1.45	1.52	1.60	1.67	1.75
	R_c	0.22	0.30	0.37	0.45	0.52	0.60	0.67	0.75	0.82	0.90
	HC	6.8	9.0	11.3	13.5	15.8	18.0	2.3	22.5	24.8	27.0
144	U-factor	0.96	0.91	.086	0.81	0.78	0.74	0.71	0.68	0.65	0.63
	C-factor	5.26	4.00	3.23	2.63	2.27	2.00	1.79	1.59	1.45	1.33
	R_u	1.04	1.10	1.16	1.23	1.29	1.35	1.41	1.48	1.54	1.60
	R_c	0.19	0.25	0.31	0.38	0.44	0.50	0.56	0.63	0.69	0.75
	HC	7.2	9.6	12.0	14.4	16.8	19.2	21.6	24.0	26.4	28.8

The U-factors and R_u include standard air film resistances.
The C-factors and R_c are for the same assembly without air film resistances.
Note that the following assemblies do not qualify as a mass wall or mass floor:
3 in. thick concrete with densities of 85, 95, 125, and 135 lb/ft³.

TABLE A3.1C Assembly U-Factors, C-Factors, R_u, R_c, and Heat Capacity for Concrete Block Walls

Product Size: in.	Density: lb/ft^3 Properties	Properties	Concrete Block Grouting and Cell Treatment				
			Solid Grouted	Partly Grouted, Cells Empty	Partly Grouted, Cells Insulated	Unreinforced, Cells Empty	Unreinforced, Cells Insulated
6 in. block	85	U-factor	0.57	0.46	0.34	0.40	0.20
		C-factor	1.11	0.75	0.47	0.60	0.23
		R_u	1.75	2.18	2.97	2.52	5.13
		R_c	0.90	1.33	2.12	1.67	4.28
		HC	10.9	6.7	7.0	4.2	4.6
	95	U-factor	0.61	0.49	0.36	0.42	0.22
		C-factor	1.25	0.83	0.53	0.65	0.27
		R_u	1.65	2.06	2.75	2.38	4.61
		R_c	0.80	1.21	1.90	1.53	3.76
		HC	11.4	7.2	7.5	4.7	5.1
	105	U-factor	0.64	0.51	0.39	0.44	0.24
		C-factor	1.38	0.91	0.58	0.71	0.30
		R_u	1.57	1.95	2.56	2.26	4.17
		R_c	0.72	1.10	1.71	1.41	3.32
		HC	11.9	7.7	7.9	5.1	5.6
	115	U-factor	0.66	0.54	0.41	0.46	0.26
		C-factor	1.52	0.98	0.64	0.76	0.34
		R_u	1.51	1.87	2.41	2.16	3.79
		R_c	0.66	1.02	1.56	1.31	2.94
		HC	12.3	8.1	8.4	5.6	6.0
	125	U-factor	0.70	0.56	0.45	0.49	0.30
		C-factor	1.70	1.08	0.73	0.84	0.40
		R_u	1.44	1.78	2.23	2.04	3.38
		R_c	05.9	0.93	1.38	1.19	2.53
		HC	12.8	8.6	8.8	6.0	6.5
	135	U-factor	0.73	0.60	0.49	0.53	0.35
		C-factor	1.94	1.23	0.85	0.95	0.49
		R_u	1.36	1.67	2.02	1.90	2.89
		R_c	0.51	0.82	1.17	1.05	2.04
		Rc	13.2	9.0	9.3	6.5	6.9
8 in. block	85	U-factor	0.49	0.41	0.28	0.37	0.15
		C-factor	0.85	0.63	0.37	0.53	0.17
		R_u	2.03	2.43	3.55	2.72	6.62
		R_c	1.18	1.58	2.70	1.87	5.77
		HC	15.0	9.0	9.4	5.4	6.0
	95	U-factor	0.53	0.44	0.31	0.39	0.17
		C-factor	0.95	0.70	0.41	0.58	0.20
		R_u	1.90	2.29	3.27	2.57	5.92
		R_c	1.05	1.44	2.42	1.72	5.07
		HC	15.5	9.6	10.0	6.0	6.6
	105	U-factor	0.55	0.46	0.33	0.41	0.19
		C-factor	1.05	0.76	0.46	0.63	0.22
		R_u	1.81	2.17	3.04	2.44	5.32
		R_c	0.96	1.32	2.19	1.59	4.47
		HC	16.1	10.2	10.6	6.6	7.2
	115	U-factor	0.58	0.48	0.35	0.43	0.21
		C-factor	1.14	0.82	0.50	0.68	0.25
		R_u	1.72	2.07	2.84	2.33	4.78
		R_c	0.87	1.22	1.99	1.48	3.93
		HC	16.7	10.8	11.2	7.2	7.8
	125	U-factor	0.61	0.51	0.38	0.45	0.24
		C-factor	1.27	0.90	0.57	0.74	0.30
		R_u	1.64	1.96	2.62	2.20	4.20
		R_c	0.79	1.11	1.77	1.35	3.35
		HC	17.3	11.4	11.8	7.8	8.4
	135	U-factor	0.65	0.55	0.42	0.49	0.28
		C-factor	1.44	1.02	0.67	0.83	0.37
		R_u	1.54	1.83	2.35	2.05	3.55
		R_c	0.69	0.98	1.50	1.20	2.70
		HC	17.9	12.0	12.4	8.4	9.0

TABLE A3.1C (continued) Assembly U-Factors, C-Factors, R_u, R_c, and Heat Capacity for Concrete Block Walls

Product Size: in.	Density: lb/ft³ Properties	Properties	Concrete Block Grouting and Cell Treatment				
			Solid Grouted	Partly Grouted, Cells Empty	Partly Grouted, Cells Insulated	Unreinforced, Cells Empty	Unreinforced, Cells Insulated
10 in. block	85	U-factor	0.44	0.38	0.25	0.35	0.13
		C-factor	0.70	0.57	0.31	0.50	0.14
		R_u	2.29	2.61	4.05	2.84	7.87
		R_c	1.44	1.76	3.20	1.99	7.02
		HC	19.0	11.2	11.7	6.5	7.3
	95	U-factor	0.47	0.41	0.27	0.37	0.14
		C-factor	0.77	0.62	0.35	0.55	0.16
		R_u	2.15	2.46	3.73	2.67	6.94
		R_c	1.30	1.61	2.88	1.82	6.09
		HC	19.7	11.9	12.4	7.3	8.1
	105	U-factor	0.49	0.43	0.29	0.39	0.16
		C-factor	0.85	0.68	0.39	0.59	0.19
		R_u	2.03	2.33	3.45	2.54	6.17
		R_c	1.18	1.48	2.60	1.69	5.32
		HC	20.4	12.6	13.1	8.0	8.8
	115	U-factor	0.52	0.45	0.31	0.41	0.18
		C-factor	0.92	0.73	0.42	0.64	0.21
		R_u	1.94	2.22	3.21	2.42	5.52
		R_c	1.09	1.37	2.36	1.57	4.67
		HC	21.1	13.4	13.9	8.7	9.5
	125	U-factor	0.54	0.48	0.34	0.44	0.21
		C-factor	1.01	0.80	0.48	0.70	0.25
		R_u	1.84	2.10	2.95	2.28	4.81
		R_c	0.99	1.25	2.10	1.43	3.96
		HC	21.8	14.1	14.6	9.4	10.2
	135	U-factor	0.58	0.51	0.38	0.47	0.25
		C-factor	1.14	0.90	0.56	0.79	0.32
		R_u	1.72	1.96	2.64	2.12	4.00
		R_c	0.87	1.11	1.79	1.27	3.15
		HC	22.6	14.8	15.3	10.2	11.0
12 in. block	85	U-factor	0.40	0.36	0.22	0.34	0.11
		C-factor	0.59	0.52	0.27	0.48	0.12
		R_u	2.53	2.77	4.59	2.93	9.43
		R_c	1.68	1.92	3.74	2.08	8.58
		HC	23.1	13.3	14.0	7.5	8.5
	95	U-factor	0.42	0.38	0.24	0.36	0.12
		C-factor	0.66	0.57	0.30	0.52	0.13
		R_u	2.30	2.60	4.22	2.76	8.33
		R_c	1.53	1.75	3.37	1.91	7.48
		HC	2.39	14.2	14.8	8.3	9.3
	105	U-factor	0.44	0.41	0.26	0.38	0.14
		C-factor	0.71	0.62	0.33	0.57	0.15
		R_u	2.25	2.47	3.90	2.62	7.35
		R_c	1.40	1.62	3.05	1.77	6.50
		HC	24.7	15.0	15.6	9.1	10.2
	115	U-factor	0.47	0.42	0.28	0.40	0.15
		C-factor	0.77	0.66	0.36	0.61	0.18
		R_u	2.15	2.36	3.63	2.49	6.54
		R_c	1.30	1.51	2.78	1.64	5.69
		HC	25.6	15.8	16.4	10.0	11.0
	125	U-factor	0.49	0.45	0.30	0.42	0.18
		C-factor	0.84	0.72	0.40	0.66	0.21
		R_u	2.04	2.23	3.34	2.36	5.68
		R_c	1.19	1.38	2.49	1.51	4.83
		HC	2.64	16.6	17.3	10.8	11.8
	135	U-factor	0.52	0.48	0.34	0.46	0.21
		C-factor	0.94	0.81	0.47	0.74	0.26
		R_u	1.91	2.08	2.98	2.19	4.67
		R_c	1.06	1.23	2.13	1.34	3.82
		HC	27.2	17.5	18.1	11.6	12.6

TABLE A3.1D Effective R-Values for Insulation/Framing Layers Added to Above-Grade Mass Walls and Below-Grade Walls

Depth (in.)	Framing Type	Rated R-Value of Insulation																									
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**
Effective R-value if continuous insulation uninterrupted by framing (includes gypsum board)																											
	None	0.5	1.5	2.5	3.5	4.5	5.5	6.5	7.5	8.5	9.5	10.5	11.5	12.5	13.5	14.5	15.5	16.5	17.5	18.5	19.5	20.5	21.5	22.5	23.5	24.5	25.5
Effective R-value if insulation is installed in cavity between framing (includes gypsum board)																											
0.5	Wood	1.3	1.3	1.9	2.4	2.7	na	na	na	na	Na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	Metal	0.9	0.9	1.1	1.1	1.2	na	na	na	na	Na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
0.75	Wood	1.4	1.4	2.1	2.7	3.1	3.5	3.8	na	na	Na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	Metal	1.0	1.0	1.3	1.4	1.5	1.5	1.6	na	na	Na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
1.0	Wood	1.3	1.5	2.2	2.9	3.4	3.9	4.3	4.6	4.9	Na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	Metal	1.0	1.1	1.4	1.6	1.7	1.8	1.8	1.9	1.9	Na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
1.5	Wood	1.3	1.5	2.4	3.1	3.8	4.4	4.9	5.4	5.8	6.2	6.5	6.8	7.1	na	na	na	na	na	na	na	na	na	na	na	na	na
	Metal	1.1	1.2	1.6	1.9	2.1	2.2	2.3	2.4	2.5	2.5	2.6	2.6	2.7	na	na	na	na	na	na	na	na	na	na	na	na	na
2.0	Wood	1.4	1.5	2.5	3.3	4.0	4.7	5.3	5.9	6.4	6.9	7.3	7.7	8.1	8.4	8.7	9.0	9.3	na	na	na	na	na	na	na	na	na
	Metal	1.1	1.2	1.7	2.1	2.3	2.5	2.7	2.8	2.9	3.0	3.1	3.2	3.3	3.3	3.4	3.4	3.4	na	na	na	na	na	na	na	na	na
2.5	Wood	1.4	1.5	2.5	3.4	4.2	4.9	5.6	6.3	6.8	7.4	7.9	8.4	8.8	9.2	9.6	10.0	10.3	10.6	10.9	11.2	11.5	na	na	na	na	na
	Metal	1.2	1.3	1.8	2.3	2.6	2.8	3.0	3.2	3.3	3.5	3.6	3.6	3.7	3.8	3.9	3.9	4.0	4.0	4.1	4.1	4.1	na	na	na	na	na
3.0	Wood	1.4	1.5	2.5	3.5	4.3	5.1	5.8	6.5	7.2	7.8	8.3	8.9	9.4	9.9	10.3	10.7	11.1	11.5	11.9	12.2	12.5	12.9	na	na	na	na
	Metal	1.2	1.3	1.9	2.4	2.8	3.1	3.3	3.5	3.7	3.8	4.0	4.1	4.2	4.3	4.4	4.4	4.5	4.6	4.6	4.7	4.7	4.8	na	na	na	na
3.5	Wood	1.4	1.5	2.6	3.5	4.4	5.2	6.0	6.7	7.4	8.1	8.7	9.3	9.8	10.4	10.9	11.3	11.8	12.2	12.6	13.0	13.4	13.8	14.1	14.5	14.8	15.1
	Metal	1.2	1.3	2.0	2.5	2.9	3.2	3.5	3.8	4.0	4.2	4.3	4.5	4.6	4.7	4.8	4.9	5.0	5.1	5.1	5.2	5.2	5.3	5.4	5.4	5.4	5.5
4.0	Wood	1.4	1.6	2.6	3.6	4.5	5.3	6.1	6.9	7.6	8.3	9.0	9.6	10.2	10.8	11.3	11.9	12.4	12.8	13.3	13.7	14.2	14.6	14.9	15.3	15.7	16.0
	Metal	1.2	1.3	2.0	2.6	3.0	3.4	3.7	4.0	4.2	4.5	4.6	4.8	5.0	5.1	5.2	5.3	5.4	5.5	5.6	5.7	5.8	5.8	5.9	5.9	6.0	6.0
4.5	Wood	1.4	1.6	2.6	3.6	4.5	5.4	6.2	7.1	7.8	8.5	9.2	9.9	10.5	11.2	11.7	12.3	12.8	13.3	13.8	14.3	14.8	15.2	15.7	16.1	16.5	16.9
	Metal	1.2	1.3	2.1	2.6	3.1	3.5	3.9	4.2	4.5	4.7	4.9	5.1	5.3	5.4	5.6	5.7	5.8	5.9	6.0	6.1	6.2	6.3	6.4	6.4	6.5	6.6
5.0	Wood	1.4	1.6	2.6	3.6	4.6	5.5	6.3	7.2	8.0	8.7	9.4	10.1	10.8	11.5	12.1	12.7	13.2	13.8	14.3	14.8	15.3	15.8	16.3	16.7	17.2	17.6
	Metal	1.2	1.4	2.1	2.7	3.2	3.7	4.1	4.4	4.7	5.0	5.2	5.4	5.6	5.8	5.9	6.1	6.2	6.3	6.5	6.6	6.7	6.8	6.8	6.9	7.0	7.1
5.5	Wood	1.4	1.6	2.6	3.6	4.6	5.5	6.4	7.3	8.1	8.9	9.6	10.3	11.0	11.7	12.4	13.0	13.6	14.2	14.7	15.3	15.8	16.3	16.8	17.3	17.8	18.2
	Metal	1.3	1.4	2.1	2.8	3.3	3.8	4.2	4.6	4.9	5.2	5.4	5.7	5.9	6.1	6.3	6.4	6.6	6.7	6.8	7.0	7.1	7.2	7.3	7.4	7.5	7.6

TABLE A3.3 Assembly U-Factors for Steel-Frame Walls

Framing Type and Spacing Width (actual depth	Cavity Insulation R-Value: Rated/ (effective installed [see Table A9.2B])	Overall U-Factor for Entire Base Wall	Overall U-Factor for Assembly of Base Wall Plus Continuous Insulation (uninterrupted by framing), Rated R-Value of Continuous Insulation																			
			R-1.00	**R-2.00**	**R-3.00**	**R-4.00**	**R-5.00**	**R-6.00**	**R-7.00**	**R-8.00**	**R-9.00**	**R-10.00**	**R-11.00**	**R-12.00**	**R-13.00**	**R-14.00**	**R-15.00**	**R-20.00**	**R-25.00**	**R-30.00**	**R-35.00**	**R-40.00**
Steel Framing at 16 in. OC																						
(3.5 in. depth)	None (0.0)	**0.352**	0.260	0.207	0.171	0.146	0.128	0.113	0.102	0.092	0.084	0.078	0.072	0.067	0.063	0.059	0.056	0.044	0.036	0.030	0.026	0.023
	R-11 (5.5)	**0.132**	0.117	0.105	0.095	0.087	0.080	0.074	0.069	0.064	0.060	0.057	0.054	0.051	0.049	0.046	0.044	0.036	0.031	0.027	0.024	0.021
	R-13 (6.0)	**0.124**	0.111	0.100	0.091	0.083	0.077	0.071	0.066	0.062	0.059	0.055	0.052	0.050	0.048	0.045	0.043	0.036	0.030	0.026	0.023	0.021
	R-15 (6.4)	**0.118**	0.106	0.096	0.087	0.080	0.074	0.069	0.065	0.061	0.057	0.054	0.051	0.049	0.047	0.045	0.043	0.035	0.030	0.026	0.023	0.021
(6.0 in. depth)	R-19 (7.1)	**0.109**	0.099	0.090	0.082	0.071	0.071	0.066	0.062	0.058	0.055	0.052	0.050	0.047	0.045	0.043	0.041	0.034	0.029	0.026	0.023	0.020
	R21 (7.4)	**0.106**	0.096	0.087	0.080	0.069	0.069	0.065	0.061	0.057	0.054	0.051	0.049	0.047	0.045	0.043	0.041	0.034	0.029	0.025	0.022	0.2
Steel Framing at 24 in. OC																						
(3.5 in. depth)	None (0.0)	**0.338**	0.253	0.202	0.168	0.126	0.126	0.112	0.100	0.091	0.084	0.077	0.072	0.067	0.063	0.059	0.056	0.044	0.036	0.030	0.026	0.023
	R-11 (6.6)	**0.116**	0.104	0.094	0.086	0.073	0.073	0.068	0.064	0.060	0.057	0.054	0.051	0.048	0.046	0.044	0.042	0.035	0.030	0.026	0.023	0.021
	R-13 (7.2)	**0.108**	0.098	0.089	0.082	0.070	0.070	0.066	0.062	0.058	0.055	0.052	0.049	0.047	0.045	0.043	0.041	0.034	0.029	0.025	0.023	0.020
	R-15 (7.8)	**0.102**	0.092	0.084	0.078	0.067	0.067	0.063	0.059	0.056	0.053	0.050	0.048	0.046	0.044	0.042	0.040	0.034	0.029	0.025	0.022	0.020
(6.0 in. depth)	R-19 (8.6)	**0.094**	0.086	0.079	0.073	0.064	0.064	0.060	0.057	0.054	0.051	0.048	0.046	0.044	0.042	0.041	0.039	0.033	0.028	0.025	0.022	0.020
	R-21 (9.0)	**0.090**	0.083	0.077	0.071	0.062	0.062	0.059	0.055	0.052	0.050	0.048	0.045	0.043	0.042	0.040	0.038	0.032	0.028	0.024	0.022	0.020

TABLE A3.4 Assembly U-Factors for Wood-Frame Walls

Framing Type and Spacing Width (actual depth)	Cavity Insulation R-Value: Rated/(effective installed [see Table A9.4C]	Overall U-Factor for Entire Base Wall	Overall U-Factor for Assembly of Base Wall Plus Continuous Insulation (uninterrupted by framing) Rated R-Value of Continuous Insulation																			
			R-1.00	**R-2.00**	**R-3.00**	**R-4.00**	**R-5.00**	**R-6.00**	**R-7.00**	**R-8.00**	**R-9.00**	**R-10.00**	**R-11.00**	**R-12.00**	**R-13.00**	**R-14.00**	**R-15.00**	**R-20.00**	**R-25.00**	**R-30.00**	**R-35.00**	**R-40.00**
Wood studs at 16 in. OC																						
(3.5 in. depth)	None (0.0)	**0.292**	0.223	0.181	0.152	0.132	0.116	0.104	0.094	0.086	0.079	0.073	0.068	0.064	0.060	0.056	0.053	0.042	0.035	0.030	0.026	0.023
	R-11 (11.0)	**0.096**	0.087	0.079	0.073	0.068	0.063	0.059	0.056	0.086	0.050	0.048	0.046	0.044	0.042	0.040	0.038	0.032	0.035	0.024	0.022	0.020
	R-13 (13.0)	**0.089**	0.080	0.074	0.068	0.063	0.059	0.056	0.053	0.053	0.047	0.045	0.043	0.041	0.040	0.038	0.037	0.031	0.028	0.024	0.021	0.019
	R-15 (15.0)	**0.083**	0.075	0.069	0.064	0.060	0.056	0.053	0.050	0.050	0.045	0.043	0.041	0.039	0.038	0.036	0.035	0.030	0.027	0.023	0.020	0.019
(5.5 in. depth)	R-16 (18.0)	**0.067**	0.062	0.058	0.054	0.051	0.048	0.046	0.044	0.042	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.027	0.024	0.021	0.019	0.018
	R-21 (21.0)	**0.063**	0.058	0.054	0.051	0.048	0.045	0.043	0.041	0.039	0.038	0.036	0.035	0.034	0.032	0.031	0.030	0.026	0.023	0.021	0.019	0.017
(+ R-10 headers)	R-19 (18.0)	**0.063**	0.059	0.055	0.052	0.049	0.047	0.045	0.043	0.041	0.039	0.038	0.036	0.035	0.034	0.033	0.031	0.027	0.024	0.021	0.019	0.017
	R-21 (21.0)	**0.059**	0.055	0.051	0.049	0.046	0.044	0.042	0.040	0.038	0.037	0.035	0.034	0.033	0.032	0.031	0.030	0.026	0.023	0.020	0.018	0.017
Wood Studs at 24 in. OC																						
(3.5 in. depth)	None (0.0)	**0.298**	0.227	0.183	0.154	0.133	0.117	0.105	0.095	0.086	0.079	0.074	0.068	0.064	0.060	0.057	0.054	0.042	0.035	0.030	0.026	0.023
	R-11 (11.0)	**0.094**	0.085	0.078	0.072	0.067	0.062	0.059	0.055	0.052	0.050	0.047	0.045	0.043	0.041	0.040	0.038	0.032	0.027	0.024	0.022	0.019
	R-13 (13.0)	**0.086**	0.078	0.072	0.067	0.062	0.058	0.055	0.052	0.049	0.047	0.045	0.043	0.041	0.039	0.038	0.036	0.031	0.026	0.023	0.021	0.019
	R-15 (15.0)	**0.080**	0.073	0.067	0.062	0.058	0.055	0.052	0.049	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.035	0.029	0.026	0.023	0.020	0.018
(5.5 in. depth)	R-19 (18.0)	**0.065**	0.060	0.056	0.053	0.050	0.047	0.045	0.043	0.041	0.039	0.038	0.036	0.035	0.034	0.033	0.032	0.027	0.024	0.021	0.019	0.018
	R-21 (21.0)	**0.060**	0.056	0.052	0.049	0.046	0.044	0.042	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.031	0.030	0.026	0.023	0.020	0.018	0.017
(+R-10 headers)	R-19 (18.0)	**0.062**	0.058	0.054	0.051	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.034	0.033	0.032	0.031	0.027	0.024	0.021	0.019	0.017
	R-21 (21.0)	**0.057**	0.053	0.050	0.047	0.045	0.043	0.041	0.039	0.037	0.036	0.035	0.033	0.032	0.031	0.030	0.029	0.025	0.023	0.020	0.018	0.017

A4 Below-Grade Walls.

A4.1 General. For the purpose of A1.2, The base assembly is 8 in. medium-weight concrete block with a density of 115 lb/ft^3 and solid grouted cores. *Continuous insulation* is installed on the interior or exterior. In contrast to the *U-factor* for *above-grade walls*, the *C-factor* for *below-grade walls* does not include R-values for exterior or interior air films or for soil. For insulated walls, the *C-factor* does include R-0.45 for 0.5 in. gypsum board.

A4.2 *C-Factors* for *Below-Grade Walls*.

A4.2.1 C-factors for below-grade walls shall be taken from Table A4.2 or determined by the procedure described in this subsection.

A4.2.2 It is acceptable to use the *C-factors* in Table A4.2 for all *below-grade walls*.

A4.2.3 If not taken from Table A4.2, *below-grade wall C-factors* shall be determined from Tables A3.1B, A3.1C, and A3.1D using the following procedure:

(a) If the *below-grade wall* is uninsulated or only the cells are insulated:

1. For concrete *walls*, determine the *C-factor* from Table A3.1B based on the concrete density and *wall* thickness.
2. For concrete block *walls*, determine the *C-factor* from Table A3.1C based on the block size, concrete density, degree of grouting in the cells, and whether the cells are insulated.

(b) If the *mass wall* has additional insulation:

1. For concrete *wall*s, determine the R_c from Table A3.1B based on the concrete density and *wall* thickness. Next, determine the effective R-value for the insulation/ framing layer from Table A3.1D based on the *rated R-value of insulation installed*, the thickness of the insulation, and whether it is installed between wood or metal framing or with no framing. Then, determine the *C-factor* by adding the R_c and the effective R-value together and taking the inverse of the total.
2. For concrete block *walls*, determine the R_c from Table A3.1C based on the block size, concrete density, degree of grouting in the cells, and whether the cells are insulated. Next, determine the effective R-value for the insulation/framing layer from Table A3.1D based on the *rated R-value of insulation* installed, the thickness of the insulation, and whether it is installed between wood or metal framing or with no framing. Then, determine the *C-factor* by adding the R_c and the effective R-value together and taking the inverse of the total.

TABLE A4.2 Assembly C-Factors for Below-Grade Walls

Framing Type and Depth	Rated R-Value of Insulation Alone	Specified C-Factors (wall only, without soil and air films)
No Framing	R-O	C-1.140
Exterior Insulation, continuous and uninterrupted by framing		
No Framing	R-5.0	C-0.170
No Framing	R-10.0	C-0.119
No Framing	R-7.5	C-0.092
No Framing	R-12.5	C-0.075
No Framing	R-15.0	C-0.063
No Framing	R-17.5	C-0.054
No Framing	R-20.0	C-0.048
No Framing	R-25.0	C-0.039
No Framing	R-30.0	C-0.032
No Framing	R-35.0	C-0.028
No Framing	R-40.0	C-0.025
No Framing	R-45.0	C-0.022
No Framing	R-50.0	C-0.020
Continuous metal framing at 24 in. on center horizontally		
3.5 in.	R-11.0	C-0.182
3.5 in.	R-15.0	C-0.174
3.5 in.	R-13.0	C-0.168
5.5 in.	R-21.0	C-0.125
5.5 in.	R-19.0	C-0.120
1 in. metal clips at 24 in. on center horizontally and 16 in. vertically		
1.0 in.	R-3.8	C-0.233
1.0 in.	R-5.6	C-0.201
1.0 in.	R-5.0	C-0.189
2.0 in.	R-7.6	C-0.138
2.0 in.	R-10.0	C-0.116
2.0 in.	R-11.2	C-0.108
2.5 in.	R-9.5	C-0.114
2.5 in.	R-14.0	C-0.096
2.5 in.	R-12.5	C-0.089
3.0 in.	R-11.4	C-0.098
3.0 in.	R-16.8	C-0.082
3.0 in.	R-15.0	C-0.076
3.5 in.	R-13.3	C-0.085
3.5 in.	R-19.6	C-0.071
3.5 in.	R-17.5	C-0.066
4.0 in.	R-15.2	C-0.076
4.0 in.	R-22.4	C-0.063
4.0 in.	R-20.0	C-0.058

A5 Floors

A5.1 General. The buffering effect of crawlspaces or parking garages shall not be included in *U-factor* calculations. See A6 for *slab-on-grade floors*.

A5.2 Mass Floors

A5.2.1 General. For the purpose of A1.2, the base assembly is *continuous insulation* over or under a solid concrete floor. The *U-factor* includes R-0.92 for interior air film—heat flow down, R-1.23 for carpet and rubber pad, R-0.50 for 8 in. concrete, and R-0.46 for semi-exterior air film.

Added insulation is continuous and uninterrupted by framing. Framing factor is zero.

A5.2.2 Rated R-Value of Insulation for Mass Floors.

A5.2.2.1 The *rated R-value of insulation* is for *continuous insulation* uninterrupted by framing.

A5.2.2.2 Where framing, including metal and wood joists, is used, compliance shall be based on the maximum assembly *U-factor* rather than the minimum *rated R-value of insulation*.

A5.2.2.3 For waffle-slab *floors*, the *floor* shall be insulated either on the interior above the slab or on all exposed surfaces of the waffle.

A5.2.2.4 For *floors* with beams that extend below the floor slab, the floor shall be insulated either on the interior above the slab or on the exposed floor and all exposed surfaces of the beams that extend 24 in. and less below the exposed floor.

A5.2.3 *U-Factors* for *Mass Floors*.

A5.2.3.1 The *U-factors* for mass walls shall be taken from Table A5.2.

A5.2.3.2 It is not acceptable to use the *U-factors* in Table A5.2 if the insulation is not continuous.

A5.3 Steel-Joist Floors.

A5.3.1 General. For the purpose of A1.2, the base assembly is a *floor* where the insulation is either placed between the steel joists or is sprayed on the underside of the *floor* and the joists. In both cases, the steel provides a thermal bypass to the insulation. The *U-factor* includes R-0.92 for interior air film—heat flow down, R-1.23 for carpet and pad, R-0.25 for 4 in. concrete, R-0 for metal deck, and R-0.46 for semi-exterior air film. The performance of the insulation/framing layer is calculated using the values in Table A9.2A.

A5.3.2 Rated R-Value of Insulation for Steel-Joist Floors

A5.3.2.1 The first *rated R-value of insulation* is for uncompressed insulation installed in the cavity between steel joists or for spray-on insulation.

A5.3.2.2 It is acceptable for this insulation to also be *continuous insulation* uninterrupted by framing. All *continuous insulation* shall be installed either on the interior above the floor structure or below a framing cavity completely filled with insulation.

A5.3.3 U-Factors for Steel-Joist Floors.

A5.3.3.1 The *U-factors* for steel-joist floors shall be taken from Table A5.3.

A5.3.3.2 It is acceptable to use these *U-factors* for any *steel-joist floor*.

A5.4 Wood-Framed and Other Floors.

A5.4.1 General. For the purpose of A1.2, the base assembly is a *floor* attached directly to the top of the wood joist and with insulation located directly below the *floor*, with a ventilated airspace below the insulation. The heat flow path through the joist is calculated to be the same depth as the insulation. The *U-factor* includes R-0.92 for interior air film— heat flow down, R-1.23 for carpet and pad, R-0.94 for 0.75 in. wood subfloor, and R-0.46 for semi-exterior air film. The weighting factors are 91% insulated cavity and 9% framing.

A5.4.2 Rated R-Value of Insulation for Wood-Framed and Other Floors

A5.4.2.1 The first *rated R-value of insulation* is for uncompressed insulation installed in the cavity between wood joists.

A5.4.2.2 It is acceptable for this insulation to also be *continuous insulation* uninterrupted by framing. All *continuous insulation* shall be installed either on the interior above the floor structure or below a framing cavity completely filled with insulation.

A5.4.3 *U-Factors for Wood-Framed Floors*.

A5.4.3.1 The *U-factors* for wood-framed floors shall be taken from Table A5.4.

A5.4.3.2 It is not acceptable to use these *U-factors* if the framing is not wood.

TABLE A5.2 Assembly U-Factors for Mass Floors

Framing Type and Spacing Width (actual depth)	Cavity Insulation R-Value: Rated/ (effective Installed)	Overall U-Factor for Entire Base Floor Assembly	Overall U-Factor for Assembly of Base Floor Plus Continuous Insulation (uninterrupted by framing) Rated R-Value of Continuous Insulation																			
			R-1.00	**R-2.00**	**R-3.00**	**R-4.00**	**R-5.00**	**R-6.00**	**R-7.00**	**R-8.00**	**R-9.00**	**R-10.00**	**R-11.00**	**R-12.00**	**R-13.00**	**R-14.00**	**R-15.00**	**R-20.00**	**R-25.00**	**R-30.00**	**R-35.00**	**R-40.00**
Concrete Floor with Rigid Foam																						
	None (0.0)	**0.322**	0.243	0.196	0.164	0.141	0.123	0.110	0.099	0.090	0.83	0.076	0.071	0.066	0.062	0.058	0.055	0.043	0.036	0.030	0.026	0.023
Concrete Floor with Pinned Boards																						
	R-4.2 (4.2)	**0.137**	0.121	0.108	0.097	0.089	0.081	0.075	0.070	0.065	0.061	0.058	0.055	0.052	0.049	0.047	0.045	0.037	0.031	0.031	0.024	0.021
	R-6.3 (6.3)	**0.107**	0.096	0.088	0.081	0.075	0.070	0.065	0.061	0.058	0.054	0.052	0.049	0.047	0.045	0.043	0.041	0.034	0.029	0.029	0.023	0.020
	R-8.3 (8.3)	**0.087**	0.080	0.074	0.069	0.065	0.061	0.057	0.054	0.051	0.049	0.047	0.045	0.043	0.041	0.039	0.038	0.032	0.027	0.027	0.022	0.019
	R-10.4 (10.4)	**0.074**	0.069	0.064	0.060	0.057	0.054	0.051	0.049	0.046	0.044	0.042	0.041	0.039	0.038	0.036	0.035	0.030	0.026	0.026	0.021	0.019
	R-12.5 (12.5)	**0.064**	0.060	0.057	0.054	0.051	0.048	0.046	0.044	0.042	0.041	0.039	0.038	0.036	0.035	0.034	0.033	0.028	0.025	0.022	0.020	0.018
	R-14.6 (14.6)	**0.056**	0.053	0.051	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.035	0.034	0.033	0.032	0.031	0.027	0.023	0.021	0.019	0.017
	R-16.7 (16.7)	**0.051**	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.035	0.034	0.032	0.031	0.030	0.030	0.029	0.025	0.022	0.020	0.018	0.017
Concrete Floor with Spray –on Insulation																						
(1 in.)	R-4 (4.0)	**0.141**	0.123	0.110	0.099	0.090	0.083	0.076	0.071	0.066	0.062	0.058	0.055	0.052	0.050	0.047	0.045	0.037	0.031	0.027	0.024	0.021
(2 in.)	R-8 (8.0)	**0.090**	0.083	0.076	0.071	0.066	0.062	0.058	0.055	0.052	0.050	0.047	0.045	0.043	0.041	0.040	0.038	0.032	0.028	0.024	0.022	0.020
(3 in.)	R-12 (12.0)	**0.066**	0.062	0.58	0.055	0.052	0.050	0.047	0.045	0.043	0.041	0.040	0.038	0.037	0.036	0.034	0.033	0.028	0.025	0.022	0.020	0.018
(4 in.)	R-16 (16.0)	**0.052**	0.050	0.047	0.045	0.043	0.041	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.031	0.030	0.029	0.026	0.023	0.020	0.018	0.017
(5 in.)	R-20 (20.0)	**0.043**	0.041	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.028	0.027	0.026	0.023	0.021	0.019	0.017	0.016
(6 in.)	R-24 (24.0)	**0.037**	0.036	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.028	0.027	0.026	0.026	0.025	0.024	0.024	0.021	0.019	0.018	0.016	0.015

TABLE A5.3 Assembly U-Factors for Steel

Framing Type and Spacing Width (actual depth)	Cavity Insulation R-Value: Rated/ (effective Installed [See Table A-9.2A])	Overall U-Factor for Entire Base Floor Assembly	Overall U-Factor for Assembly of Base Floor Plus Continuous Insulation (uninterrupted by framing) Rated R-Value of Continuous Insulation																			
			R-1.00	**R-2.00**	**R-3.00**	**R-4.00**	**R-5.00**	**R-6.00**	**R-7.00**	**R-8.00**	**R-9.00**	**R-10.00**	**R-11.00**	**R-12.00**	**R-13.00**	**R-14.00**	**R-15.00**	**R-20.00**	**R-25.00**	**R-30.00**	**R-35.00**	**R-40.00**
Steel Joist Floor with Rigid Foam																						
	None (0.0)	**0.350**	0.259	0.206	0.171	0.146	0.127	0.113	0.101	0.092	0.084	0.078	0.072	0.067	0.063	0.059	0.056	0.044	0.036	0.030	0.026	0.023
Steel Joist Floor with spray-on Insulation																						
(1 in.)	R-4 (3.88)	**0.148**	0.129	0.114	0.103	0.093	0.085	0.078	0.073	0.068	0.064	0.060	0.056	0.053	0.051	0.048	0.046	0.037	0.032	0.027	0.024	0.021
(2 in.)	R-8 (7.52)	**0.096**	0.088	0.081	0.075	0.070	0.065	0.061	0.058	0.054	0.052	0.049	0.047	0.045	0.043	0.041	0.039	0.033	0.028	0.025	0.022	0.020
(3 in.)	R-12 (10.80)	**0.073**	0.068	0.064	0.060	0.057	0.054	0.051	0.048	0.046	0.044	0.042	0.041	0.039	0.038	0.036	0.035	0.030	0.026	0.023	0.021	0.019
(4 in.)	R-16 (13.92)	**0.060**	0.056	0.053	0.051	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.035	0.034	0.032	0.031	0.027	0.024	0.021	0.019	0.018
(5 in.)	R-20 (17.00)	**0.050**	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.035	0.033	0.032	0.031	0.030	0.030	0.029	0.025	0.022	0.020	0.018	0.017
(6 in.)	R-24 (19.68)	**0.044**	0.042	0.041	0.039	0.038	0.036	0.035	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.027	0.027	0.024	0.021	0.019	0.017	0.016
Steel Joist Floor with Batt Insulation																						
	None (0.0)	**0.350**	0.259	0.206	0.171	0.146	0.127	0.113	0.101	0.092	0.084	0.078	0.072	0.067	0.063	0.059	0.056	0.044	0.036	0.030	0.026	0.023
	R-11 (10.01)	**0.078**	0.072	0.067	0.063	0.059	0.056	0.053	0.050	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.030	0.026	0.023	0.021	0.019
	R-13 (11.70)	**0.069**	0.064	0.060	0.057	0.054	0.051	0.049	0.046	0.044	0.042	0.041	0.039	0.038	0.036	0.035	0.034	0.029	0.025	0.022	0.020	0.018
	R-15 (13.20)	**0.062**	0.059	0.055	0.052	0.050	0.047	0.045	0.043	0.042	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.028	0.024	0.022	0.020	0.018
	R-19 (16.34)	**0.052**	0.050	0.047	0.045	0.043	0.041	0.040	0.038	0.037	0.035	0.034	0.033	0.032	0.031	0.030	0.029	0.026	0.023	0.020	0.018	0.017
	R-21 (17.64)	**0.049**	0.047	0.044	0.043	0.041	0.039	0.038	0.036	0.035	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.025	0.022	0.020	0.018	0.017
	R-25 (20.25)	**0.043**	0.041	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.028	0.027	0.026	0.023	0.021	0.019	0.017	0.016
	R-30C (23.70)	**0.038**	0.036	0.035	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.027	0.027	0.026	0.025	0.025	0.024	0.021	0.019	0.018	0.016	0.015
	R-30 (23.70)	**0.038**	0.036	0.035	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.027	0.027	0.026	0.025	0.025	0.024	0.021	0.019	0.018	0.016	0.015
	R-38C (28.12)	**0.032**	0.031	0.030	0.029	0.029	0.028	0.027	0.026	0.026	0.025	0.024	0.024	0.023	0.023	0.022	0.022	0.020	0.018	0.016	0.015	0.014
	R-38 (28.12)	**0.032**	0.031	0.030	0.029	0.029	0.028	0.027	0.026	0.026	0.025	0.024	0.024	0.023	0.023	0.022	0.022	0.020	0.018	0.016	0.015	0.014

TABLE 5.4 Assembly U-Factors for Wood-Joist Floors

Framing Type and Spacing Width	Cavity Insulation R-Value: Rated/ (effective installed)	Overall U-Factor for Entire Base Floor Assembly	Overall U-Factor for Assembly of Base Floor Plus Continuous Insulation (uninterrupted by framing) Rated R-Value of Continuous Insulation																			
			R-1.00	R-2.00	R-3.00	R-4.00	R-5.00	R-6.00	R-7.00	R-8.00	R-9.00	R-10.00	R-11.00	R-12.00	R-13.00	R-14.00	R-15.00	R-16.00	R-17.00	R-18.00	R-19.00	R-20.00
Wood Joists																						
	None	**0.282**	0.220	0.180	0.153	0.132	0.117	0.105	0.095	0.087	0.080	0.074	0.069	0.064	0.060	0.057	0.054	0.042	0.035	0.030	0.026	0.023
(5.5 in.)	R-11 (11.0)	**0.074**	0.069	0.064	0.060	0.057	0.054	0.051	0.048	0.046	0.044	0.042	0.040	0.039	0.037	0.036	0.035	0.030	0.026	0.023	0.020	0.019
	R-13 (13.0)	**0.066**	0.062	0.058	0.055	0.052	0.049	0.047	0.045	0.043	0.041	0.039	0.038	0.036	0.035	0.034	0.033	0.028	0.025	0.022	0.020	0.018
	R-15 (15.0)	**0.060**	0.057	0.053	0.050	0.048	0.046	0.044	0.042	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.031	0.027	0.024	0.021	0.019	0.017
	R-19 (18.0)	**0.051**	0.048	0.046	0.044	0.042	0.040	0.038	0.037	0.036	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.025	0.022	0.020	0.018	0.017
	R-21 (21.0)	**0.046**	0.043	0.042	0.040	0.038	0.037	0.035	0.034	0.033	0.032	0.031	0.030	0.029	0.028	0.027	0.027	0.023	0.021	0.019	0.017	0.016
(7.25 in.)	R-25 (25.0)	**0.039**	0.037	0.036	0.035	0.033	0.032	0.031	0.030	0.029	0.028	0.028	0.027	0.026	0.025	0.025	0.024	0.022	0.019	0.018	0.016	0.015
	R-30C (30.0)	**0.034**	0.033	0.032	0.031	0.030	0.029	0.028	0.027	0.026	0.026	0.025	0.024	0.024	0.023	0.023	0.022	0.020	0.018	0.016	0.015	0.014
(9.25 in.)	R-30 (30.0)	**0.033**	0.032	0.031	0.030	0.029	0.028	0.027	0.027	0.026	0.025	0.024	0.024	0.023	0.023	0.022	0.022	0.020	0.018	0.016	0.015	0.014
(11.25 in.)	R-38C (38.0)	**0.027**	0.026	0.025	0.025	0.024	0.024	0.023	0.022	0.022	0.021	0.021	0.020	0.020	0.020	0.019	0.019	0.017	0.016	0.015	0.014	0.013
(13.25 in.)	R-38 (38.0)	**0.026**	0.026	0.025	0.024	0.024	0.023	0.023	0.022	0.022	0.021	0.021	0.020	0.020	0.019	0.019	0.019	0.017	0.016	0.015	0.014	0.013

A6 Slab-on-Grade Floors.

A6.1 General. For the purpose of A1.2, the base assembly is a slab floor of 6 in. concrete poured directly on to the earth, the bottom of the slab is at grade line, and soil conductivity is 0.75 Btu/h·ft·°F. In contrast to the *U-factor* for *floors*, the *F-factor* for *slab-on-grade floors* is expressed per lineal foot of building perimeter. *F-factors* are provided for unheated slabs and for heated slabs. *Unheated slab-on-grade floors* do not have heating elements, and *heated slab-on-grade floors* do have heating elements within or beneath the slab. F-factors are provided for three insulation configurations:

(a) **Horizontal insulation:** ***Continuous insulation*** is applied directly to the underside of the slab and extends inward horizontally from the perimeter for the distance specified or ***continuous insulation*** is applied downward from the top of the slab and then extends horizontally to the interior or the exterior from the perimeter for the distance specified.

(b) **Vertical insulation:** *continuous insulation* is applied directly to the slab exterior, extending downward from the top of the slab for the distance specified.

(c) **Fully insulated slab:** *continuous insulation* extends downward from the top of the slab and along the entire perimeter and completely covers the entire area under the slab.

A6.2 Rated R-Value of Insulation for Slab-on-Grade Floors.

A6.2.1 The *rated R-value of insulation* shall be installed around the perimeter of the *slab-on-grade floor* to the distance specified.

Exception to A6.2.1: For a monolithic *slab-on-grade floor*, the insulation shall extend from the top of the slab-on-grade to the bottom of the footing.

A6.2.2 Insulation installed inside the foundation wall shall extend downward from the top of the slab a minimum of the distance specified or to the top of the footing, whichever is less.

A6.2.3 Insulation installed outside the foundation wall shall extend from the top of the slab or downward to at least the bottom of the slab and then horizontally to a minimum of the distance specified. In all climates, the horizontal insulation extending outside of the foundation shall be covered by pavement or by soil a minimum of 10 in. thick.

A6.3 F-Factors for Slab-on-Grade Floors.

A6.3.1 *F-factors* for slab-on-grade floors shall be taken from Table A6.3.

A6.3.2 These *F-factors* are acceptable for all *slab-on-grade floors*.

TABLE A6.3 Assembly F-Factors for Slab-on-Grade Floors

Insulation Description	Rated R-Value of Insulation												
	R-0	R-5	R-7.5	R-10	R-15	R-20	R-25	R-30	R-35	R-40	R-45	R-50	R-55
Unheated Slabs													
None	0.73												
12 in. horizontal		0.72	0.71	0.71	0.71								
24 in. horizontal		0.70	0.70	0.70	0.69								
36 in. horizontal		0.68	0.67	0.66	0.66								
48 in. horizontal		0.67	0.65	0.64	0.63								
12 in. vertical		0.61	0.60	0.58	0.57	0.567	0.565	0.564					
24 in. vertical		0.58	0.56	0.54	0.52	0.510	0.505	0.502					
36 in. vertical		0.56	0.53	0.51	0.48	0.472	0.464	0.460					
48 in. vertical		0.54	0.51	0.48	0.45	0.434	0.424	0.419					
Fully insulated slab		0.46	0.41	0.36	0.30	0.261	0.233	0.213	0.198	0.186	0.176	0.168	0.161
Heated Slabs													
None	1.35												
12 in. horizontal		1.31	1.31	1.30	1.30								
24 in. horizontal		1.28	1.27	1.26	1.25								
36 in. horizontal		1.24	1.21	1.20	1.18								
48 in. horizontal		1.20	1.17	1.13	1.11								
12 in. vertical		1.06	1.02	1.00	0.98	0.968	0.964	0.961					
24 in. vertical		0.99	0.95	0.90	0.86	0.843	0.832	0.827					
36 in. vertical		0.95	0.89	0.84	0.79	0.762	0.747	0.740					
48 in. vertical		0.91	0.85	0.78	0.72	0.688	0.671	0.659					
Fully insulated slab		0.74	0.64	0.55	0.44	0.373	0.326	0.296	0.273	0.255	0.239	0.227	0.217

A7 Opaque Doors. All *opaque doors* with *U-factors* determined, certified, and labeled in accordance with NFRC 100 shall be assigned those *U-factors*.

A7.1 Unlabeled Opaque Doors. Unlabeled *opaque doors* shall be assigned the following *U-factors*:

(a) Uninsulated single-layer metal *swinging doors* or *non-swinging doors*, including single-layer uninsulated *access hatches* and uninsulated smoke vents: 1.45

(b) Uninsulated double-layer metal *swinging doors* or *non-swinging doors*, including double-layer uninsulated *access hatches* and uninsulated smoke vents: 0.70

(c) Insulated metal *swinging doors*, including fire-rated *doors*, insulated *access hatches*, and insulated smoke vents: 0.50

(d) Wood *doors*, minimum nominal thickness of 1 3/4 in., including panel *doors* with minimum panel thickness of 1 1/8 in., solid core flush *doors*, and hollow core flush *doors*: 0.50.

(e) Any other wood *door*: 0.60

A8 Fenestration. All *fenestration* with *U-factors*, *SHGC*, or visible light transmittance determined, certified, and labeled in accordance with NFRC 100, 200, and 300, respectively, shall be assigned those values.

A8.1 Unlabeled Skylights. Unlabeled *skylights* shall be assigned the *U-factors* in Table A8.1A and are allowed to use the *SHGC*s and visible light transmittances in Table A8.1B. The metal with thermal break frame category shall not be used unless all frame members have a thermal break equal to or greater than 1/4 in.

TABLE A8.1A Assembly U-Factors for Unlabeled Skylights

Product Type		Sloped Insulation: Unlabeled Skylight with Curb (Includes glass/plastic, flat/domed, fixed/operable)				Sloped Insulation: Unlabeled Skylight without Curb (Includes glass/plastic, flat/domed, fixed/operable)		
ID	**Frame Type / Glazing Type**	**Aluminum without Thermal Break**	**Aluminum with Thermal Break**	**Reinforced Vinyl/Aluminum Clad Wood**	**Wood/Vinyl**	**Aluminum without Thermal Break**	**Aluminum with Thermal Break**	**Structural Glazing**
	Single Glazing							
1	1/8 Glass	1.98	1.89	1.75	1.47	1.36	1.25	1.25
2	¼” acrylic/polycarb	1.82	1.73	1.60	1.31	1.21	1.10	1.10
3	1/8" acrylic/polycarb	1.90	1.81	1.68	1.39	1.29	1.18	1.18
	Doubling Glazing							
4	1/4" airspace	1.31	1.11	1.05	0.84	0.82	0.70	0.66
5	1/2" airspace	1.30	1.10	1.04	0.84	0.81	0.69	0.65
6	1/4" argon space	1.27	1.07	1.00	0.80	0.77	0.66	0.62
7	1/2" argon space	1.27	1.07	1.00	0.80	0.77	0.66	0.62
	Double Glazing, *e*=0.60 on surface 2 or 3							
8	1/4" airspace	1.27	1.08	1.01	0.81	0.78	0.67	0.63
9	1/2" airspace	1.27	1.07	1.00	0.80	0.77	0.66	0.62
10	1/4" argon space	1.23	1.03	0.97	0.76	0.74	0.63	0.58
11	1/2" argon space	1.23	1.03	0.97	0.76	0.74	0.63	0.58
	Double Glazing, *e*=0.40 on surface 2 or 3							
12	1/4" airspace	1.25	1.05	0.99	0.78	0.76	0.64	0.60
13	1/2" airspace	1.24	1.04	0.98	0.77	0.75	0.64	0.59
14	1/4" argon space	1.18	0.99	0.92	0.72	0.70	0.58	0.54
15	1/2" argon space	1.20	1.00	0.94	0.74	0.71	0.60	0.56
	Double Glazing, *e*=0.20 on surface 2 or 3							
16	1/4" airspace	1.20	1.00	0.94	0.74	0.71	0.60	0.56
17	1/2" airspace	1.20	1.00	0.94	0.74	0.71	0.60	0.56
18	1/4" argon space	1.14	0.94	0.88	0.68	0.65	0.54	0.50
19	1/2" argon space	1.15	0.95	0.89	0.68	0.66	0.55	0.51
	Double Glazing, *e*=0.10 on surface 2 or 3							
20	1/4" airspace	1.18	0.99	0.92	0.72	0.70	0.58	0.54
21	1/2" airspace	1.18	0.99	0.92	0.72	0.70	0.58	0.54
22	1/4" argon space	1.11	0.91	0.85	0.65	0.63	0.52	0.47
23	1/2" argon space	1.13	0.93	0.87	0.67	0.65	0.53	0.49
	Double Glazing, *e*=0.05 on surface 2 or 3							
24	1/4" airspace	1.17	0.97	0.91	0.70	0.68	0.57	0.52
25	1/2" airspace	1.17	0.98	0.91	0.71	0.69	0.58	0.53
26	1/4" argon space	1.09	0.89	0.83	0.63	0.61	0.50	0.45
27	1/2" argon space	1.11	0.91	0.85	0.65	0.63	0.52	0.47
	Triple Glazing							
28	1/4" airspaces	1.12	0.89	0.84	0.64	0.64	0.53	0.48
29	1/2" airspaces	1.10	0.87	0.81	0.61	0.62	0.51	0.45
30	1/4" argon spaces	1.09	0.86	0.80	0.60	0.61	0.50	0.44
31	1/2" argon spaces	1.07	0.84	0.79	0.59	0.59	0.48	0.42
	Triple Glazing, *e*=0.20 on surface 2,3,4, or 5							
32	1/4" airspaces	1.08	0.85	0.79	0.59	0.60	0.49	0.43
33	1/2" airspaces	1.05	0.82	0.77	0.57	0.57	0.46	0.41
34	1/4" argon spaces	1.02	0.79	0.74	0.54	0.55	0.44	0.38
35	1/2" argon spaces	1.01	0.78	.073	0.53	0.54	0.43	0.37

TABLE A8.1A (*continued*) Assembly U-Factors for Unlabeled Skylights

Product Type		Sloped Insulation						
		Unlabeled Skylight with Curb (Includes glass/plastic, flat/domed, fixed/operable)				Unlabeled Skylight without Curb (Includes glass/plastic, flat/domed, fixed/operable)		
Frame Type		Aluminum without Thermal Break	Aluminum with Thermal Break	Reinforced Vinyl/Aluminum Clad Wood	Wood/Vinyl	Aluminum without Thermal Break	Aluminum with Thermal Break	Structural Glazing
ID	**Glazing Type**							
	Triple Glazing, e=0.20 on surfaces 2 or 3 and 4 or 5							
36	1/4" airspaces	1.03	0.80	0.75	0.55	0.56	0.45	0.39
37	1/2" airspaces	1.01	0.78	0.73	0.53	0.54	0.43	0.37
38	1/4" argon spaces	0.99	0.75	0.70	0.50	0.51	0.40	0.35
39	1/2" argon spaces	0.97	0.74	0.69	0.49	0.50	0.39	0.33
	Triple Glazing, *e*=0.10 on surfaces 2 or 3 and 4 or 5							
40	1/4" airspaces	1.01	0.78	0.73	0.53	0.54	0.43	0.37
41	1/2" airspaces	0.99	0.76	0.71	0.51	0.52	0.41	0.36
42	1/4" argon spaces	0.96	0.73	0.68	0.48	0.49	0.38	0.32
43	1/2" argon spaces	0.95	0.72	0.67	0.47	0.48	0.37	0.31
	Quadruple Glazing, e=0.10 on surfaces 2 or 3 and 4 or 5							
44	1/4" airspaces	0.97	0.74	0.69	0.49	0.50	0.39	0.33
45	1/2" airspaces	0.94	0.71	0.66	0.46	0.47	0.36	0.30
46	1/4" argon spaces	0.93	0.70	0.65	0.45	0.46	.035	0.30
47	1/2" argon spaces	0.91	0.68	0.63	0.43	0.44	0.33	0.28
48	1/4" krypton spaces	0.88	0.65	0.60	0.40	0.42	0.31	0.25

TABLE A8.1B Assembly Solar Heat Gain Coefficients (SHGC) and Assembly Visible Light Transmittances (VLT) for Unlabeled Skylights

Glass Type	Glazing Type: Number of glazing layers Number and emissivity of coatings (glazing is glass except where noted)	Unlabeled Skylights (includes glass/plastic, flat/domed, fixed/operable)						
		Frame:	Metal without thermal break		Metal with thermal break		Wood/vinyl/ fiberglass	
		Characteristic:	SHGC	VLT	SHGC	VLT	SHGC	VLT
Clear	Single glazing, 1/8 in. glass		0.82	0.76	0.78	0.76	0.73	0.73
	Single glazing, 1/4 in. glass		0.78	0.75	0.74	0.75	0.69	0.72
	Single glazing, acrylic/polycarbonate		0.83	0.92	0.83	0.92	0.83	0.92
	Double glazing		0.68	0.66	0.64	0.66	0.59	0.64
	Double glazing, E=0.40 on surface 2 or 3		0.71	0.65	0.67	0.65	0.62	0.63
	Double glazing, E=0.20 on surface 2 or 3		0.66	0.61	0.62	0.61	0.57	0.59
	Double glazing, E=0.10 on surface 2 or 3		0.59	0.63	0.55	0.63	0.51	0.61
	Double glazing, acrylic/polycarbonate		0.77	0.89	0.77	0.89	0.77	0.89
	Triple glazing		0.60	0.59	0.56	0.59	0.52	0.57
	Triple glazing, E=0.40 on surface 2, 3, 4, or 5		0.64	0.60	0.60	0.60	0.56	0.57
	Triple glazing, E=0.20 on surface 2, 3, 4, or 5		0.59	0.55	0.55	0.55	0.51	0.53
	Triple glazing, E=0.10 on surface 2, 3, 4, or 5		0.54	0.56	0.50	0.56	0.46	0.54
	Triple glazing, E=0.40 on surfaces 3 and 5		0.62	0.57	0.58	0.57	0.53	0.55
	Triple glazing, E=0.20 on surfaces 3 and 5		0.56	0.51	0.52	0.51	0.48	0.49
	Triple glazing, E=0.10 on surfaces 3 and 5		0.47	0.54	0.43	0.54	0.40	0.52
	Triple glazing, acrylic/polycarbonate		0.71	0.85	0.71	0.85	0.71	0.85
	Quadruple glazing, E=0.10 on surfaces 3 and 5		0.41	.048	0.37	0.48	0.33	0.46
	Quadruple glazing, acrylic/polycarbonate		0.65	0.81	0.65	0.81	0.65	0.81
Tinted	Single glazing, 1/8 in. glass		0.70	0.58	0.66	0.58	0.62	0.56
	Single glazing, 1/4 in. glass		0.61	0.45	0.56	0.45	0.52	0.44
	Single glazing, acrylic/polycarbonate		0.46	0.27	0.46	0.27	0.46	0.27
	Double glazing		0.50	0.40	0.46	0.40	0.42	0.39
	Double glazing, E=0.40 on surface 2 or 3		0.59	0.50	0.55	0.50	0.50	0.48
	Double glazing, E=0.20 on surface 2 or 3		0.47	0.37	0.43	0.37	0.39	0.36
	Double glazing, E=0.10 on surface 2 or 3		0.43	0.38	0.39	0.38	0.35	0.37
	Double glazing, acrylic/polycarbonate		0.37	0.25	0.37	0.25	0.37	0.25
	Triple glazing		0.42	0.22	0.37	0.22	0.34	0.21
	Triple glazing, E=0.40 on surface 2, 3, 4, or 5		0.53	0.45	0.49	0.45	0.45	0.44
	Triple glazing, E=0.20 on surface 2, 3, 4, or 5		0.42	0.33	0.38	0.33	0.35	0.32
	Triple glazing, E=0.10 on surface 2, 3, 4, or 5		0.39	0.34	0.35	0.34	0.31	0.33
	Triple glazing, E=0.40 on surfaces 3 and 5		0.51	0.43	0.47	0.43	0.43	0.42
	Triple glazing, E=0.20 on surfaces 3 and 5		0.40	0.31	0.36	0.31	0.32	0.29
	Triple glazing, E=0.10 on surfaces 3 and 5		0.34	0.32	0.30	0.32	0.27	0.31
	Triple glazing, acrylic/polycarbonate		0.30	0.23	0.30	0.23	0.30	0.23
	Quadruple glazing, E=0.10 on surfaces 3 and 5		0.30	0.29	0.26	0.29	0.23	0.28
	Quadruple glazing, acrylic/polycarbonate		0.27	0.25	0.27	0.25	0.27	0.25

TABLE A8.2 Assembly U-Factors, Assembly Solar Heat Gain Coefficients (SHGC), and Assembly Visible Light Transmittances (VLT) for Unlabeled Vertical Fenestration

Frame Type	Glazing Type	Unlabeled Vertical Fenestration					
		Clear Glass			Tinted Glass		
		U-Factor	SHGC	VLT	U-Factor	SHGC	VLT
All frame types							
	Single glazing	1.25	0.82	0.76	1.25	0.70	0.58
	Glass block	0.60	0.56	0.56	n.a.	n.a.	n.a.
Wood, vinyl, or fiberglass frame							
	Double glazing	0.60	0.59	0.64	0.60	0.42	0.39
	Triple glazing	0.45	0.52	0.57	0.45	0.34	0.21
Metal and other frame type							
	Double glazing	0.90	0.68	0.66	0.90	0.50	0.40
	Triple glazing	0.70	0.60	0.59	0.70	0.42	0.22

A8.2 Unlabeled Vertical Fenestration. Unlabeled *vertical fenestration*, both operable and fixed, shall be assigned the *U-factors*, *SHGC*s, and visible light transmittances in Table A8.2.

A9 Determination of Alternate Assembly U-Factors, C-Factors, F-Factors, or Heat Capacities

A9.1 General. Component *U-factors* for other opaque assemblies shall be determined in accordance with A9 only if approved by the *building official* in accordance with A1.2. The procedures required for each class of construction are specified in A9.2. Testing shall be performed in accordance with A9.3. Calculations shall be performed in accordance with A9.4.

A9.2 Required Procedures. Two- or three-dimensional finite difference and finite volume computer models shall be an acceptable alternative method to calculating the thermal performance values for all assemblies and constructions listed below. The following procedures shall also be permitted to determine all alternative *U-factors*, *F-factors*, and *C-factors*.

(a) **Roofs**.

1. *Roofs with insulation entirely above deck*: testing or series calculation method.
2. *Metal building roofs*: testing.
3. *Attic roofs*, wood joists: testing or parallel path calculation method.
4. *Attic roofs*, steel joists: testing or parallel path calculation method using the insulation/framing layer adjustment factors in Table A9.2A or modified zone calculation method.
5. *Attic roofs*, concrete joists: testing or parallel path calculation method if concrete is solid and uniform or isothermal planes calculation method if concrete has hollow sections.
6. Other *attic roofs* and other *roofs*: testing or two-dimensional calculation method.

(b) **Above-Grade Walls**.

1. *Mass walls*: testing or the isothermal planes calculation method or two-dimensional calculation method. The parallel path calculation method is not acceptable.
2. *Metal building walls*: testing.
3. *Steel-framed walls*: testing or parallel path calculation method using the insulation/framing layer adjustment factors in Table A9.2B or the modified zone method.
4. *Wood-framed walls*: testing or parallel path calculation method.
5. Other *walls*: testing or two-dimensional calculation method.

(c) **Below-Grade Walls**.

1. *Mass walls*: testing or the isothermal planes calculation method or two-dimensional calculation method. The parallel path calculation method is not acceptable.
2. *Other walls*: testing or two-dimensional calculation method.

(d) **Floors**.

1. *Mass floors*: testing or parallel path calculation method if concrete is solid and uniform or isothermal planes calculation method if concrete has hollow sections.
2. *Steel joist floors*: testing or modified zone calculation method.
3. *Wood joist floors*: testing or parallel path calculation method or isothermal planes calculation method.
4. Other *floors*: testing or two-dimensional calculation method.

(e) **Slab-on-Grade Floors**: no testing or calculations allowed.

TABLE A9.2A Effective Insulation/Framing Layer R-Values for Roof and Floor Insulation Installed Between Metal Framing (4 ft on center)

Rated R-Value of Insulation	Correction Factor	Framing/Cavity R-Value		Rated R-Value of Insulation	Correction Factor	Framing/Cavity R-Value
0.00	1.00	0.00		20.00	0.85	17.00
4.00	0.97	3.88		21.00	0.84	17.64
5.00	0.96	4.80		24.00	0.82	19.68
8.00	0.94	7.52		25.00	0.81	20.25
10.00	0.92	9.20		30.00	0.79	23.70
11.00	0.91	10.01		35.00	0.76	26.60
12.00	0.90	10.80		38.00	0.74	28.12
13.00	0.90	11.70		40.00	0.73	29.20
15.00	0.88	13.20		45.00	0.71	31.95
16.00	0.87	13.92		50.00	0.69	34.50
19.00	0.86	16.34		55.00	0.67	36.85

TABLE A9.2B Effective Insulation/Framing Layer R-Values for Wall Insulation Installed Between Steel Framing

Nominal Depth of Cavity (in.)	Actual Depth of Cavity (in.)	Rated R-Value of Airspace or Insulation	Effective Framing/Cavity R-Value at 16 in. on center	Effective Framing/Cavity at 24 in. on center
		Empty cavity, no insulation		
4	3.5	R-0.91	0.79	0.91
		Insulated Cavity		
4	3.5	R-11	5.5	6.6
4	3.5	R-13	6.0	7.2
4	3.5	R-15	6.4	7.8
6	6.0	R-19	7.1	8.6
6	6.0	R-21	7.4	9.0
8	8.0	R-25	7.8	9.6

A9.3 Testing Procedures.

A9.3.1 Building Material Thermal Properties. If *building material* R-values or thermal conductivities are determined by testing, one of the following test procedures shall be used:

(a) ASTM C177,

(b) ASTM C518, or

(c) ASTM C1363

For concrete, the oven-dried conductivity shall be multiplied by 1.2 to reflect the moisture content as typically installed.

A9.3.2 Assembly U-Factors. If assembly *U-factors* are determined by testing, ASTM C1363 test procedures shall be used.

Product samples tested shall be production line material or representative of material as purchased by the consumer or contractor. If the assembly is too large to be tested at one time in its entirety, then either a representative portion shall be tested or different portions shall be tested separately and a weighted average determined. To be representative, the portion tested shall include edges of panels, joints with other panels, typical framing percentages, and thermal bridges.

A9.4 Calculation Procedures and Assumptions. The following procedures and assumptions shall be used for all calculations. R-values for air films, insulation, and *building materials* shall be taken from A9.4.1 through A9.4.3, respectively. In addition, the appropriate assumptions listed in A2 through A8, including framing factors, shall be used.

A9.4.1 Air Films. Prescribed R-values for air films shall be as follows:

R-Value	Condition
0.17	All exterior surfaces
0.46	All semi-exterior surfaces
0.61	Interior horizontal surfaces, heat flow up
0.92	Interior horizontal surfaces, heat flow down
0.68	Interior vertical surfaces

A9.4.1.1 Exterior surfaces are areas exposed to the wind.

A9.4.1.2 Semi-exterior surfaces are protected surfaces that face attics, crawlspaces, and parking garages with natural or mechanical ventilation.

A9.4.1.3 Interior surfaces are surfaces within enclosed spaces.

A9.4.1.4 The R-value for cavity airspaces shall be taken from Table A9.4A based on the emissivity of the cavity from Table A9.4B. No credit shall be given for airspaces in cavities that contain any insulation or are less than 0.5 in. The values for 3.5 in. cavities shall be used for cavities of that width and greater.

A9.4.2 Insulation R-Values. Insulation R-values shall be determined as follows:

(a) For insulation that is not compressed, the *rated R-value of insulation* shall be used.

(b) For calculation purposes, the effective R-value for insulation that is uniformly compressed in confined cavities be taken from Table A9.4C.

(c) For calculation purposes, the effective R-value for insulation installed in cavities in attic roofs with steel joists shall be taken from Table A9.2.A.

(d) For calculation purposes, the effective R-value for insulation installed in cavities in steel-framed walls shall be taken from Table A9.2B.

A9.4.3 Building Material Thermal Properties. R-values for *building materials* shall be taken from Table A9.4D. Concrete block R-values shall be calculated using the isothermal planes method or a two-dimensional calculation program, thermal conductivities from Table A9.4E, and dimensions from ASTM C90. The parallel path calculation method is not acceptable.

Exception to A9.4.3: R-values for *building materials* or thermal conductivities determined from testing in accordance with A9.3.

A9.4.4 Building Material Heat Capacities: The *heat capacity* of assemblies shall be calculated using published values for the unit weight and specific heat of all building material components that make up the assembly.

TABLE A9.4A Values for Cavity Air Spaces

Component	Airspace Thickness (in.)	R-Value				
		Effective Emissivity				
		0.03	0.05	0.20	0.50	0.82
Roof	0.50	2.13	2.04	1.54	1.04	0.77
	0.75	2.33	2.22	1.64	1.09	0.80
	1.50	2.53	2.41	1.75	1.13	0.82
	3.50	2.83	2.66	1.88	1.19	0.85
Wall	0.50	2.54	2.43	1.75	1.13	0.82
	0.75	3.58	3.32	2.18	1.30	0.90
	1.50	3.92	3.62	2.30	1.34	0.93
	3.50	3.67	3.40	2.21	1.31	0.91
Floor	0.50	2.55	1.28	1.00	0.69	0.53
	0.75	1.44	1.38	1.06	0.73	0.54
	1.50	2.49	2.38	1.76	1.15	0.85
	3.50	3.08	2.90	2.01	1.26	0.90

TABLE A9.4B Emittance Values of Various Surfaces and Effective Emittances of Air Spaces

Surface	Average Emittance *e*	Effective Emittance *e eff* of Air Space	
		One Surface *e*; Other, 0.9	Both Surfaces Emittance *e*
Aluminum foil, bright	0.05	0.05	0.03
Aluminum foil, with condensate just visible (>0.7 gr/ft^2)	0.30	0.29	-
Aluminum foil, with condensate clearly visible (>2.9 gr/ft^2)	0.70	0.65	-
Aluminum sheet	0.12	0.12	0.06
Aluminum coated paper, polished	0.20	0.20	0.11
Steel, galv., bright	0.25	0.24	0.15
Aluminum paint	0.50	0.47	0.35
Bldg materials: wood, paper, masonry, nonmetallic paints	0.90	0.82	0.82
Regular glass	0.84	0.77	0.72

TABLE A9.4C Effective R-Values for Fiberglass

Insulation R-Value at Standard Thickness									
Rated R-Value		38	30	22	21	19	15	13	11
Standard Thickness (in.)		12	9.5	6.5	5.5	6	3.5	3.5	3.5
Nominal Lumber Size (in.)	Actual Depth of Cavity (in.)	Effective Insulation R-Values when Installed in a Confined Cavity							
2 × 12	11.25	37	-	-	-	-	-	-	-
2 × 10	9.25	32	30	-	-	-	-	-	-
2 × 8	7.25	27	26	22	21	19	-	-	-
2 × 6	5.5	-	21	20	21	18	-	-	-
2 × 4	3.5	-	-	14	-	13	15	13	11
	2.5	-	-	-	-	-	-	9.8	-
	1.5	-	-	-	-	-	-	6.3	6

TABLE A9.4D R-Values for Building Materials

Material	Nominal Size (in.)	Actual Size (in.)	R-Value
Carpet and rubber pad	-	-	1.23
Concrete at R-0.0625/in.	-	2	0.13
	-	4	0.25
	-	6	0.38
	-	8	0.5
	-	10	0.63
	-	12	0.75
Flooring, wood subfloor	-	0.75	0.94
Gypsum board	-	0.5	0.45
	-	0.625	0.56
Metal deck	-	-	0
Roofing, built-up	-	0.375	0.33
Sheathing, vegetable fiber board, 0.78 in.	-	0.78	2.06
Soil at R-0.104/in.	-	12	1.25
Steel, mild		1	0.0031807
Stucco	-	0.75	0.08
Wood, 2 × 4 at R-1.25/in.	4	3.5	4.38
Wood, 2 × 6 at R-1.25/in.	6	5.5	6.88
Wood, 2 × 8 at R-1.25/in.	8	7.25	9.06
Wood, 2 × 10 at R-1.25/in.	10	9.25	11.56
Wood, 2 × 12 at R-1.25/in.	12	11.25	14.06
Wood, 2 × 14 at R-1.25/in.	14	13.25	16.56

TABLE A9.4E Thermal Conductivity of Concrete Block Material

Concrete Block Density in lb/ft3	Thermal Conductivity in Btu·in./h·ft^2·°F
80	3.7
85	4.2
4.7	4.7
95	5.1
100	5.5
105	6.1
110	6.7
115	7.2
120	7.8
125	8.9
130	10.0
135	11.8
140	13.5

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(This is a normative appendix and is part of this code.)

NORMATIVE APPENDIX B

BUILDING ENVELOPE CLIMATE CRITERIA

B1 General. This normative appendix provides the information to determine both United States and international climate zones. For U.S. locations, use either Figure B-1 or Table B-1 to determine the climate zone number and letter that are required for determining compliance regarding various sections and tables in this code. Figure B-1 contains the county-by-county climate zone map for the United States. Table B-1 lists each state and major counties within the state and shows the climate number and letter for each county listed.

Table B-2 shows the climate zone number for a wide variety of Canadian locations. When the climate zone letter is required to determine compliance with this code, refer to Table B-4 and the Major Climate Type Definitions in Section B2 to determine the letter (A, B, or C).

Table B-3 shows the climate zone number for a wide variety of other international locations besides Canada. When the climate zone letter is required to determine compliance with this code, refer to Table B-4 and the Major Climate Type Definitions in Section B2 to determine the letter (A, B, or C).

For all international locations that are not listed either in Table B-2 or B-3, use Table B-4 and the Major Climate Type Definitions in Section B2 to determine both the climate zone letter and number.

Note: CDD50 and HDD65 values may be found in Normative Appendix D.

B2 Major Climate Type Definitions. Use the following information along with Table B-4 to determine climate zone numbers and letters for international climate zones. Marine (C) definition—Locations meeting all four criteria:

1. Mean temperature of coldest month between 27°F and 65°F
2. Warmest month mean < 72°F
3. At least four months with mean temperatures over 50°F
4. Dry season in summer. The month with the heaviest precipitation in the cold season has at least three times as much precipitation as the month with the least precipitation in the rest of the year. The cold season is October through March in the Northern Hemisphere and April through September in the Southern Hemisphere.

Dry (B) definition—Locations meeting the following criteria:

not marine and

$P_{in} < 0.44 \times (TF - 19.5)$

where

P = annual precipitation in inches and

T = annual mean temperature in °F.

Moist (A) definition—Locations that are not marine and not dry.

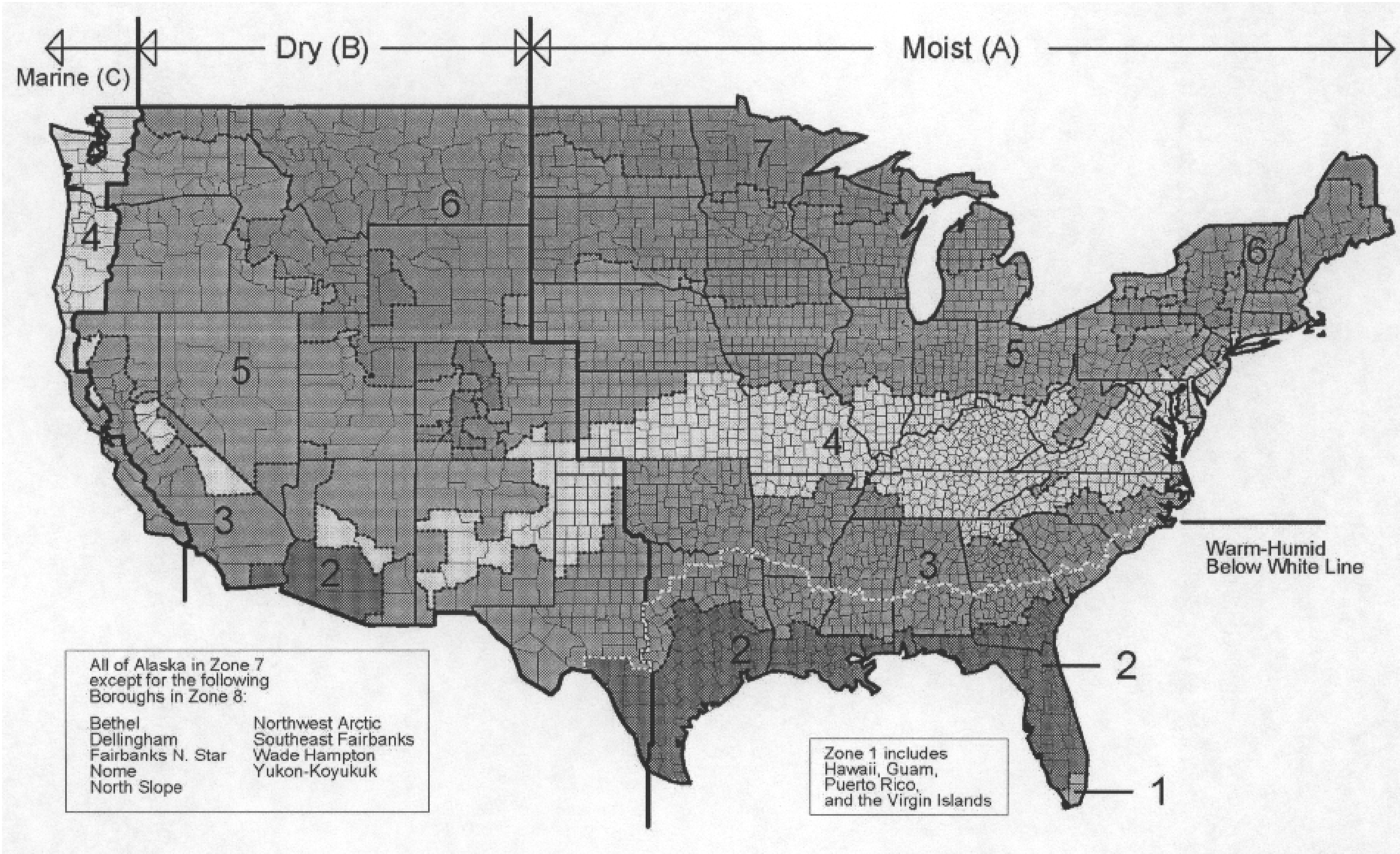

Figure B-1 Climate zones for United States locations.

TABLE B-4 International Climate Zone Definitions

Zone Number	Name	Thermal Criteria
1	Very Hot – Humid (1A) Dry (1B)	9000 < CDD50°F
2	Hot – Humid (2A), Dry (2B)	6300 < CDD50°F ≤ 9000
3A and 3B	Warm – Humid (3A), Dry (3B)	4500 < CDD50°F ≤ 6300
3C	Warm – Marine	CDD50°F ≤ 4500 AND HDD65°F ≤ 3600
4A and 4B	Mixed – Humid (4A), Dry (4B)	CDD50°F ≤ 4500 AND 3600 < HDD65°F ≤ 5400
4C	4C Mixed – Marine	3600 < HDD65°F ≤ 5400
5A, 5B and 5C	Cool– Humid (5A), Dry (5B), Marine (5C)	5400 < HDD65°F ≤ 7200
6A and 6B	Cold – Humid (6A), Dry (6B)	7200 < HDD65°F ≤ 9000
7	Very Cold	9000 < HDD65°F ≤ 12600
8	Subarctic	12600 < HDD65°F

(This is a normative appendix and is part of this code.)

NORMATIVE APPENDIX C

METHODOLOGY FOR BUILDING ENVELOPE TRADE-OFF OPTION IN SUBSECTION 5.6

C1 Minimum Information

The following minimum information shall be specified for the proposed design.

C1.1 At the Building Level: The floor area, broken down by *space-conditioning categories*.

C1.2 At the Exterior Surface Level: The classification, gross area, orientation, *U-factor*, and exterior conditions. For *mass walls* only: *heat capacity* and insulation position. Each surface is associated with a *space-conditioning category* as defined in C1.1.

C1.3 For Fenestration: The classification, area, *U-factor*, *solar heat gain coefficient* (SHGC), visible light transmittance (VLT), *overhang projection factor for vertical fenestration*, and width, depth, and height for *skylight wells*. (See Figure C1.3 for definition of width, depth, and height for *skylight wells*.) Each *fenestration* element is associated with a surface (defined in C1.2) and has the orientation of that surface.

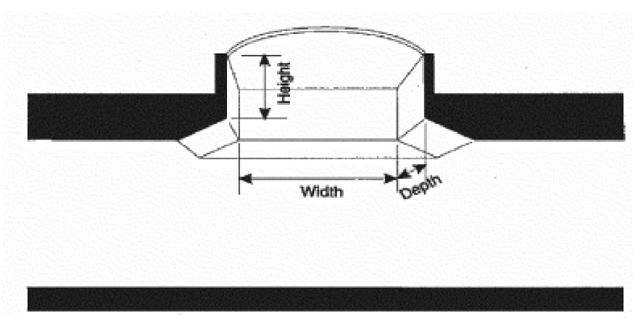

Figure C1.3 Skylight well dimensions.

C1.4 For Opaque Doors: The classification, area, *U-factor*, *heat capacity*, and insulation position. Each *opaque door* is associated with a surface (defined in C1.2) and has the orientation of that surface.

C1.5 For Below-Grade Walls: The area, average depth to the bottom of the wall, and *C-factor*. Each *below-grade wall* is associated with a *space-conditioning category* as defined in C1.1.

C1.6 For Slab-On-Grade Floor: The perimeter length and F-factor. Each slab-on-grade floor is associated with a space-conditioning category as defined in C1.1.

C2 Output Requirements

Output reports shall contain the following information.

C2.1 Tables summarizing the minimum information described in C1.

C2.2 The *envelope performance factor* differential broken down by envelope component. The differential is the difference between the *envelope performance factor* of the proposed building and the *envelope performance factor* of the base envelope design. Envelope components include the *opaque roof*, *skylights*, *opaque above-grade walls* including *vertical fenestration* and *opaque doors*, *below-grade walls*, *floors*, and *slab-on-grade floors*.

C3 Base Envelope Design Specification

C3.1 The base envelope design shall have the same building floor area, *building envelope floor area*, *slab-on-grade floor* perimeter, below-grade floor area, gross *wall area*, *opaque door area*, and *gross roof area* as the proposed design. The distribution of these areas among *space-conditioning categories* shall be the same as the proposed design.

C3.2 The *U-factor* of each *opaque* element of the base envelope design shall be equal to the criteria from Table 5.5-2 for the appropriate climate for each construction classification. *The heat capacity of mass wall* elements in the base envelope design shall be identical to the proposed design. *Mass walls* in the base envelope design shall have interior insulation, when required.

C3.3 The *vertical fenestration area* of each *space-conditioning category* in the base envelope design shall be the same as the proposed building or 40% of the *gross wall area*, whichever is less. The distribution of *vertical fenestration* among *space-conditioning categories* and surface orientations shall be the same as the proposed design. If the *vertical fenestration* area of any *space-conditioning category* is greater than 40% of the *gross wall area* of that *space-conditioning category*, then the area of each *fenestration* element shall be reduced in the base envelope design by the same percentage so that the total *vertical fenestration area* is exactly equal to 40% of the *gross wall area*.

C3.4 The *skylight area* of each space category in the base envelope design shall be the same as the proposed building or 5% of the *gross roof area*, whichever is less. This distribution of *skylights* among *space conditioning categories* shall be the same as the proposed design. If the *skylight* area of any space category is greater than 5% of the *gross roof area* of that *space-conditioning category*, then the area of each *skylight* shall be reduced in the base envelope design by the same percentage so that the total *skylight* area is exactly equal to 5% of the *gross roof area*.

C3.5 The *U-factor* for *fenestration* in the base envelope design shall be equal to the criteria from Table 5.5-2 for the appropriate climate. The *solar heat gain coefficient* (*SHGC*) for *fenestration* in the base envelope design shall be equal to the criteria from Table 5.5-2 shall be equal to 0.64 for *north-*

oriented and 0.46 for all other *vertical fenestration*, 0.77 for plastic *skylights* on a curb, and 0.72 for all other *skylights* with a curb and without. The visible light transmittance (VLT) for *fenestration* in the base envelope design shall be the VLT factor from Table C3.5 times the *SHGC* criteria as determined in this subsection.

TABLE C3.5 VLT Factor for the Base Envelope Design

Climate Bin	Vertical Fenestration	Glass Skylights	Plastic Skylights
1(A,B)	1.00	1.27	1.20
2(A,B)	1.00	1.27	1.20
3(C)	1.00	1.27	1.20
3(A,B)	1.27	1.27	1.20
4(A,B,C)	1.27	1.27	1.20
5(A,B,C)	1.27	1.27	1.20
6(A,B)	1.27	1.27	1.20
7	1.00	1.00	1.20
8	1.00	1.00	1.20

C4 Zoning and Building Geometry

No information about thermal zones needs to be entered to perform the calculations, but when the calculations are performed the building shall be divided into thermal zones according to the following procedure.

C4.1 Determine the ratio (*Rc*) of the *gross floor area* to the *gross wall area* for each *space-conditioning category*. The index “c” refers to the *space-conditioning category*, either *nonresidential conditioned*, *residential conditioned*, or *semi-heated*.

C4.2 Create a perimeter zone for each unique combination of *space-conditioning category* and *wall orientation*. The *floor area* of each perimeter zone shall be the *gross wall area* of the zone times *Rc* or 1.25, whichever is smaller.

C4.3 For *space-conditioning categories* where *Rc* is greater than 1.25, interior zones shall be created and used in the trade-off procedure. The *floor area* of the interior zone shall be the total floor area for the *space-conditioning category* less the floor area of the perimeter zones created in C4.2 for that *space-conditioning category*.

C4.4 *Roof area*, *floor area*, *below-grade wall area*, and *slab-on-grade floor* perimeter associated with each *space-conditioning category* shall be prorated among the zones according to *floor area*.

C4.5 *Skylights* shall be assigned to the interior zone of the *space-conditioning category*. If the *skylight area* is larger than the *roof area* of the interior zone, then the *skylight area* in the interior zone shall be equal to the *roof area* in the interior zone and the remaining *skylight area* shall be prorated among the perimeter zones based on *floor area*.

C5 Modeling Assumptions

The following are modeling assumptions for the purposes of this appendix only and are not requirements for building operation.

C5.1 The *residential conditioned* and *nonresidential conditioned space-conditioning categories* shall be modeled with both heating and cooling systems for both the base envelope design and the proposed design. The thermostat setpoints for *residential* and *nonresidential spaces* shall be 70°F for heating and 75°F for cooling, with night setback temperatures of 55°F for heating and 99°F for cooling.

C5.2 The *semiheated* space categories shall be modeled with heating-only systems for both the base envelope design and the proposed design. The thermostat setpoint shall be 50°F for all hours.

C5.3 Both the base envelope design and the proposed design shall be modeled with the same heating, ventilating, and air-conditioning (HVAC) systems. The system shall consist of a packaged rooftop system serving each thermal zone. Cooling shall be provided by a direct expansion air conditioner (EER = 9.5, $COP_{cooling}$ = 2.78). Heating shall be provided by a gas furnace (AFUE = 0.78).

C5.4 The electrical systems shall be the same for both the base envelope design and the proposed design. The lighting power density shall be 1.20 W/ft^2 for *nonresidential conditioned spaces*, 1.00 W/ft^2 for *residential conditioned spaces*, and 0.50 W/ft^2 for *semiheated spaces*. The equipment power density shall be 0.75 W/ft^2 for *nonresidential conditioned spaces*, 0.25 W/ft^2 for *residential conditioned spaces*, and 0.25 W/ft^2 for *semi-heated spaces*. Continuous daylight dimming shall be assumed in all spaces and be activated at 50 fc for *nonresidential conditioned spaces* and *residential conditioned spaces* and 30 fc for *semiheated spaces*.

C5.5 Surface reflectances for daylighting calculations shall be 80% for ceilings, 50% for walls, and 20% for floors.

C5.6 *Envelope performance factor* is defined in the following equation.

$$\text{Envelope Performance Factor} = \frac{\text{MBtu} \times 6600 + \text{kWh} \times 80}{\text{Total Building Floor Area}} \qquad \text{(C-1)}$$

C5.7 The *U-factor* entered for surfaces adjacent to crawlspaces, attics, and parking garages with mechanical or natural ventilation shall be adjusted by adding R-2 to the *thermal resistance* to account for the buffering effect.

C5.8 Heat transfer for *below-grade walls* shall be based on the temperature difference between indoor and outdoor temperature conditions and a heat transfer path at the average wall depth below grade.

C6 Equations for Envelope Trade-Off Calculations

The procedure defined in this subsection shall be used in all building envelope trade-off calculations.

C6.1 Inputs. Building descriptions shall be converted to equation variables using Table C6.1.

TABLE C6.1 Input Variables

Variables	Description	I-P Units
$Area_{surface}$	Area of surface	ft^2
$Area_{zone}$	Gross floor area of zone as defined in C.5	ft^2
C-factor	C-factor for below-grade walls	$Btu/h \cdot ft^2 \cdot °F$
CDD50	Cooling degree-days	Base 50°F·day
CDD65	Cooling degree-days	Base 65°F·day
CDH80	Cooling degree-hours	Base 80°F·hour
CFA	Conditioned floor area	ft^2
Depth	Depth of bottom of below-grade wall	ft
DI	Artificial lighting design illuminance from C.5.4	footcandles
DR	Daily range (average outdoor maximum-minimum in hottest month)	°F
EPD	Miscellaneous equipment power density from C.5.4	W/ft^2
F-factor	F-factor for slab-on-grade floors	Btu/h·ft·°F
FAF	Building floor area factor	1000/CFA, ft^2
HC	Wall heat capacity	$Btu/ft^2 \cdot °F$
HDD50	Heating degree-days	Base 50°F·day
HDD65	Heating degree-days	Base 65°F·day
Length	Length of slab-on-grade floor perimeter	ft
LPD	Lighting power density from C.5.4	W/ft^2
R-Value	Effective R-value of soil for below-grade walls	$h \cdot ft^2 \cdot °F/Btu$
U-factor	U-factor	$Btu/h \cdot ft^2 \cdot °F$
VS	Annual average daily incident solar radiation on vertical surface	$Btu/ft^2 \cdot day$

C6.2 Envelope Performance Factor. The *envelope performance factor* (*EPF*) of a building shall be calculated using Equation C-2.

$$EPF = FAF \times [\sum HVAC_{surface} + \sum Lighting_{zone}] \quad (C\text{-}2)$$

where

FAF = floor area factor for the entire building

$\sum HVAC_{\mathbf{surface}}$ = sum of HVAC for each surface calculated using Equation C-3

$\sum Lighting_{\mathbf{zone}}$ = sum of lighting for each zone calculated using Equation C-4

C6.3 HVAC. The HVAC term for each *exterior* or *semi-exterior* surface in the building shall be calculated using Equation C-3.

$$HVAC_{\mathbf{surface}} = COOL + HEAT$$

where

COOL = cooling factor for the surface calculated according to the appropriate equation in C-14, C-19, or C-22

HEAT = heating factor for the surface calculated according to the appropriate equation in C- 16, C-18, or C-23

C6.4 Lighting. The lighting term for each zone in the building as defined in C4 shall be calculated using Equation C-4.

$$Lighting_{\mathbf{zone}} = LPDadj_{\mathbf{zone}} \times AREA_{\mathbf{zone}} \times 216$$

where

$LPDadj_{\mathbf{zone}}$ = lighting power density for the zone adjusted for daylighting potential using Equation C-9

C6.5 Solar and Visible Aperture

C6.5.1 Solar and Visible Aperture of Vertical Fenestration. The visible aperture (VA), solar aperture for cooling (SA_c), and solar aperture for heating (SA_h) of each *vertical fenestration* shall be calculated using Equations C-5, C-6, and C-7.

$$VA = Area_{\mathbf{vf}} \times VLT_{\mathbf{vf}} \times (1 + PCC1 \times PF + PCC^2 \times PF^2) \quad (C\text{-}5)$$

$$SA_{\mathbf{c}} = Area_{\mathbf{vf}} \times 1.163 \times SHGC \times (1 - PCC1 \times PF + PCC^2 \times PF) \quad (C\text{-}6)$$

$$SA_{\mathbf{h}} = Area_{\mathbf{vf}} \times 1.163 \times SHGC \times (1 + PCH1 \times PF + PCH^2$$

$Area_{vf}$ = *glazing area* of the *vertical fenestration*

SHGC = the *solar heat gain coefficient* of the *vertical fenestration* assembly

VLT_{vf} = the visible light transmittance of the *vertical fenestration* assembly

PF = the *projection factor* for the overhang shade on the *vertical fenestration*

PCH1, PCH^2, PCC1, and PCC^2 = overhang projection coefficients for the *vertical fenestration orientation* from Table C6.5.1

TABLE C6.5.1 Overhang Projection Coefficients

Orientation	PCC1	PCC2	PCH1	PCH2
North	–0.5 0	0.22	0	0
East, South, West	–0.97	0.38	0	0

C6.5.2 Visible Aperture of Skylights. The visible aperture (VA) of a *skylight* shall be calculated using Equation C-8.

$$VA = Area_{sky} \times VLT_{sky} \times 10^{(-0.250 \times (5 \times D \times (W + L) / (W \times L))} \quad \text{(C-8)}$$

where

$Area_{sky}$ = *fenestration area* of the *skylight* assembly

VLT_{sky} = the visible light transmittance of the *skylight* assembly

D = average depth of skylight well from *fenestration* to ceiling

W = width of skylight well

L = length of skylight well

C6.6 Adjusted Lighting Power (LPDadj). The adjusted lighting power for each zone shall be calculated using Equation C-9.

$$LPDadj_{zone} = LPD \times (1 - Kd_{zone}) \quad \text{(C-9)}$$

where Kd_{zone} = daylight potential fraction calculated using Equation C-10.

If a zone has both *skylights* and *vertical fenestration*, the larger of the *Kd* calculated independently for each shall be used to calculate LPDadj.

$$Kd_{zone} = \left(\Phi 1 + \left(\frac{\Phi 2 x DI x VA}{Area_{fen}}\right)\right) \times \left(1 - e^{((\Phi 3 + \Phi 4 \times DI) \times (VA/Area_{surface})}\right) \quad \text{(C-10)}$$

where

$Area_{fen}$ = total *fenestration area* of the *vertical fenestration* or *skylight* assemblies in the zone

VA = total visible aperture of the *vertical fenestration* or *skylights* in the zone, as calculated in C-5

$Area_{surface}$ = *gross wall area* of the zone for *vertical fenestration* or *gross roof area* of the zone for *skylights*

and the coefficients 1 through 4 are defined in Table C6.6.

TABLE C6.6 Coefficients for Calculating ^{K}d

Coefficient	Skylight	Vertical Fenestration
Φ1	0.589	0.737
Φ2	5.18E–07	–3.17E-04
Φ3	–220	–24.71
Φ4	2.29	0.234

C6.7 Delta Load Factors for Mass Walls in the Exterior Building Envelope. Adjustments to cooling and heating loads for use in Equations C-14 and C-16 due to the mass properties of each *mass wall* component shall be calculated using Equations C-11 and C-12.

$$CMC = 1.43 \times Area_{mw} \times [1 - e^{-CP_1 (HC - 1)}] \times \left[CP_2 + CP_3 U - \left(\frac{CP_4}{1 + (CP_5 + CP_6 U) e^{-(CP_7 + CP_8 U^2)(HC-1)}}\right)\right] \quad \text{(C-11)}$$

where

CMC = cooling delta load factor

$Area_{mw}$ = net *opaque area* of this *mass* wall

A_C = CDH80/10000 + 2

B = DR/10 + 1

HC = wall heat capacity

DR = average daily temperature range for warmest month

B = DR/10 +1

CP_1 = C_5

CP_2 = $C_{15}/B^3 + C_{16}/(A_C^2 B^2) + C_{17}$

CP_3 = $C_1/A_C^3 + C_2B^3 + C_2B^3 + C^3/(A_C^2 \sqrt{B}) + C_4$

CP_4 = $C_{12}(A_C^2B^2) + C_{13}/B^3 + C_{14}$

U = area average of *U-factors* of *mass walls* in the zone

CP_5 = C_{18}

CP_6 = $C_6 \sqrt{B}\, LN(A_C) + C_7$

LN = natural logarithm

CP_7 = $C_{19}/(A_C^2B^2) + C_{20}/(A_CB) + C_{21}A_C/\sqrt{B} + C_{22}$

$$CP_8 = C_8/(A_C^2B^2) + C_9/(A_CB) + C_{10}A_C^2/\sqrt{B} + C_{11}$$

The coefficients C_1 through C_{22} depend on insulation position in the wall and are taken from Table C6.7A.

$$HMC = 1.43 \times Area_{mw} \times [1 - e^{-HP_1(HC-1)}] \times \left[HP_2 + HP_3U - \left(\frac{CP_4}{1 + (HP_5 + HP_6U)e^{-(HP_7 + HP_8U^2)(HC-1)}}\right)\right] \quad \text{(C-12)}$$

where

HMC = heating delta load factor

HC = wall heat capacity

$Area_{mw}$ = net *opaque area* of this *mass* wall

HP_1 = H_6

AH = $HDD65/100 + 2$

HP_2 = $H_{14}LN(A_H) + H_{15}$

LN = natural logarithm

HP_3 = $H_1A_H^3 + H_2A_H^2 + H_3/\sqrt{A} + H_4\sqrt{A} + H_5$

U = area average of *U-factors* of *mass walls* in the zone

HP_4 = $H_{11}A_H^2 + H_{12}/A_H^2 + H_{13}$

HP_5 = H_{16}

HP_6 = $H_7A_H + H_8$

HP_7 = $H_{17}/A_H^3 + H_{18}$

HP_8 = $H_9/A_H3 + H_{10}$

The coefficients H_1 through H_{18} depend on the position of the insulation in the wall and are taken from Table C6.7B. If the *U-factor* of *mass wall* is greater than 0.4 Btu/(h·ft²·°F), then the *U-factor* shall be set to 0.4 Btu/(h·ft²·°F). If the *U-factor* of *the mass wall* is less than 0.05 Btu/(h·ft²·°F), then the *U-Factor* shall be set to 0.05 Btu/(h·ft²·°F). If the wall heat capacity (HC) of the *mass wall* is greater than 20 Btu/(ft²·°F), then HC = 20 Btu/(ft²·°F) shall be used.

TABLE C6.7A Cooling Delta Load Coefficients

	Insulation Position		
Variable	**Exterior**	**Integral**	**Interior**
C_1	220.7245	139.1057	181.6168
C_2	-0.0566	-0.0340	0.0552
C_3	118.8354	10.3267	31.1590
C_4	13.6744	20.8674	25.5919
C_5	0.2364	0.2839	0.0810
C_6	0.9596	0.3059	1.4190
C_7	0.2550	0.0226	0.4324
C_8	905.6780	307.9438	188.9268
C_9	425.1919	80.2096	443.1958
C_{10}	2.5106	0.0500	0.4302
C_{11}	43.3880	5.9895	28.2851
C_{12}	259.7234	11.3961	63.5623
C_{13}	33.9755	0.3669	20.8447
C_{14}	20.4882	30.2535	9.8175
C_{15}	26.2092	8.8337	24.4598
C_{16}	241.1734	22.2546	70.3375
C_{17}	18.8978	29.3297	9.8843
C_{18}	0.3538	0.0239	0.1146
C_{19}	156.3056	63.228	326.3447
C_{20}	74.0990	16.3347	77.6355
C_{21}	0.4454	0.0111	0.0748
C_{22}	7.4967	1.2956	5.2041

TABLE C6.7B Heating Delta Load Coefficients

	Insulation Position		
Variable	**Exterior**	**Integral**	**Interior**
H_1	0.0000	0.0000	0.0000
H_2	0.0015	0.0018	0.0015
H_3	13.3886	15.1161	19.8314
H_4	1.9332	2.1056	1.4579
H_5	11.8967	13.3053	15.5620
H_6	0.4643	0.1840	0.0719
H_7	0.0094	0.0255	0.0264
H_8	0.1000	0.0459	0.7754
H_9	1223.3962	622.0801	0.2008
H_{10}	0.9454	0.5192	0.6379
H_{11}	0.0001	0.0001	0.0000
H_{12}	3.8585	4.1379	2.4243
H_{13}	7.5829	6.2380	7.9804
H_{14}	0.7774	0.7711	0.1699
H_{15}	9.0147	7.7229	8.5854
H_{16}	0.2007	0.2083	0.0386
H_{17}	206.6382	105.9849	3.1397
H_{18}	0.2573	0.1983	0.1863

C6.8 Walls and Vertical Fenestration in the Exterior Building Envelope. Equations C-14 and C-16 shall be used to calculate COOL and HEAT for *exterior walls* and *vertical fenestration* in the *exterior building envelope* except walls next to crawlspaces, attics, and parking garages with natural or mechanical ventilation. *Walls* next to crawlspaces, attics, and parking garages with natural or mechanical ventilation shall use the equations in subsection C6.10 and they shall not be included in calculations in subsection C6.8. Zones shall be constructed according to C4 and the HEAT and COOL for the combination of all *exterior walls* and *vertical fenestration* in the zone shall be calculated using Equations C-14 and C-16, which include interactive effects. For a zone having a cardinal *orientation* (north, east, south, or west), Equations C-14 and C-15 shall be applied directly. For zones with northeast, northwest, southwest, and southeast *orientations*, EC shall be determined by finding the average of the values for the two closest cardinal *orientations*; for instance, COOL for a *wall* facing northeast is calculated by taking the average of COOL for a north-facing wall and COOL for an east-facing *wall*.

C6.8.1 Effective Internal Gain. The effective internal gain to the zone G shall be calculated using Equation C-13.

$$G = EPD + LPDadj_{zone} \quad \text{(C-13)}$$

where

$LPDadj_{zone}$ = lighting power density adjusted for daylighting, from Equation C-9

C.6.8.2 Cooling Factor. The cooling factor for the surfaces in the zone shall be calculated using Equation C-14.

$$COOL = 0.005447 \times [CLU + CLUO + CLXUO + CLM + CLG + CLS + CLC] \quad \text{(C-14)}$$

where

CLU = $Area_{opaque} \times U_{ow} \times [CU1 \times CDH80 + CU2 \times CDH80^2 + CU3 \times (VS \times CDH80)^2 + CU4 \text{ x } DR]$

CLUO = $Area_{grosswall} \times UO \times [CUO1 \times EA_C \times VS \times CDD50 + CUO2 \times G + CUO3 \times G^2 \times EA_C^2 \times VS \times CDD50 + CUO4 \times G^2 \times EA_C^2 \times VS \times CDD65]$

CLXUO = $Area_{grosswall} / UO \times [CXUO1 \times EA_C \times VS \times CDD50 + CXUO2 \times EA_C \times (VS \times CDD50)^2 + CXUO3 \times G \times CDD50 + CXUO4 \times G^2 \times EA_C^2 \times VS \times CDD50 + CXUO5 \times G^2 \times CDD65]$

CLM = $Area_{opaque} \times SCMC \times [CM1 + CM2 \times EA_C \times VS \times CDD50 + CM3 \times EA_C \times VS \times CDD65 + CM4 \times EA_C2 \times VS \times CDD50 + CM5 \times G^2 \times CDD65 + CM6 \times G \times CDD50 + CM7 \times G \times CDD65 + CM8 \times G \times EA_C \times VS \times CDD50]$

CLG = $Area_{grosswall} \times \{G \times [CG1 + CG2 \times CDD50 + CG3 \times EA_C \times (VS \times CDD50)2 + CG4 \times EA_C^2 \times VS \times CDD50 + CG5 \times CDD65 + CG6 \times CDD503 + CG7 \times CDD653] + G^2 \times [CG8 \times EA_C \times VS \times CDD50 + CG9 \times EA_C^2 \times VS \times CDD50]\}$

CLS = $Area_{grosswall} \times \{EA_C \times [CS1 + CS2 \times VS \times CDD50 + CS3 \times (VS \times CDD50)2 + CS4 \times VS \times CDD65 + CS5 \times (VS \times CDD65)2] + EA_C^2 \times [CS6 + CS7 \times (VS \times CDD65)2]\}$

CLC = $Area_{grosswall} \times [CC1 \times CDD50 + CC2 \times CDD502 + CC3 \times CDH80 + CC4 \times CDH802 + CC5 \times CDD65 + CC6 \times (VS \times CDD65)2 + CC7 \times VS \times CDD50 + CC8 \times (VS \times CDD50)2 + CC9 \times (VS \times CDH80)2 + CC10 \times VS + CC11 \times DR + CC12 \times DR2 + CC13]$

where

$Area_{grosswall}$ = total gross area of all *walls* and *vertical fenestration* in the zone, including *opaque* and *fenestration areas*

$Area_{opaque}$ = total *opaque area* of all *walls* in the zone

U_{ow} = area average of *U-factors* of *opaque walls* (including those of mass construction) in the zone

VS = annual average daily incident solar energy on surface

DR = average daily temperature range for the warmest month

UO = area average of *U-factor* of *opaque walls* and *vertical fenestration* in the zone

SCMC = sum of the CMC from Equation C-11 for each *mass wall* in the zone

G = effective internal gain to space, from Equation C-13

EA_C = effective solar aperture fraction for zone calculated using Equation C-15

$$EA_C = \frac{\sum SA_C}{Area_{grosswall}}$$

where

$\sum SA_C$ = the sum of SA_C from Equation C-6.6 for all *vertical fenestration* in the zone.

The coefficients used in the above equations depend on the *orientation* of the surface and shall be found in Table C6.8.2.

TABLE C6.8.2 Cooling Coefficients for the Exterior Wall Equation

	Orientation of Surface			
Variable	North	East	South	West
CU1	0.001539	0.003315	0.003153	0.00321
CU2	-3.0855E-08	-8.9662E-08	-7.1299E-08	-8.1053E-08
CU3	7.99493E-14	3.7928E-14	1.83083E-14	3.3981E-14
CU4	-0.079647	.163114	0.286458	0.11178
CM1	0.2314	0.515262	0.71477	0.752643
CM2	1.5306E-06	1.3897E-06	1.6163E-06	1.42228E-06
CM3	-2.0432E-06	-1.6024E-06	-2.1106E-06	-1.9794E-06
CM4	-7.5367E-07	-7.6785E-07	-6.6443E-07	-7.4007E-07
CM5	-1.0047E-06	0	8.01057E-06	3.15193E-06
CM6	3.66708E-05	3.645603E-05	4.48106E-05	2.96012E-05
CM7	-6.7305E-05	-6.4094E-05	-0.000119	-7.6672E-05
CM8	-2.3834E-08	-4.7253E-08	-4.974E-08	0
CUO1	6.5109E-06	8.3867E-06	8.89E-06	7.5647E-06
CUO2	1.040207	1.507235	1.512625	1.238545
CUO3	4.3825E-06	2.7883E-06	2.3135E-06	4.1257E-06
CUO4	0.000012658	8.09874E-06	7.36219e-06	10.6712E-05
CXUO1	1.03744E-06	1.19338E-06	1.18588E-06	1.23251E-06
CXUO2	1.3218E-13	1.3466E-13	1.1625E-13	1.3E-13
CXUO3	2.75554E-05	2.0621E-05	2.02365E-05	2.36964E-05
CXUO4	9.7409E-08	1.175E-07	9.39207E-08	1.36276E-07
CXUO5	1.1825E-05	9.0969E-06	9.0919E-06	1.1108E-05
CG1	0.891286	0.583388	0.939756	0.948654
CG2	0.001479	0.001931	0.002081	0.001662
CG3	-5.5204E-13	-2.8214E-13	-2.8477E-13	-4.5572E-13
CG4	2.52311E-06	3.70821E-06	4.30536E-06	5.91511E-06
CG5	-0.001151	-0.001745	-0.001864	-0.00153
CG6	1.95243E-12	0	-2.9606E-12	3.16358E-12
CG7	-8.3581E-12	1.01089E-11	3.30027E-11	0
CG8	1.41022E-06	7.53875E-07	7.133E-07	9.70752E-07
CG9	-2.3889E-06	-1.6496E-06	-1.6393E-06	-1.9736E-06
CS1	46.9871	33.9683	18.32016	29.3089
CS2	3.48091E-05	3.74118E-05	0.000034049	5.02498E-05
CS3	0	0	2.71313E-12	0
CS4	-1.6641E-05	6.94779E-06	-2.8218E-05	-2.7716E-05
CS5	8.42765E-12	0	-3.0468E-12	2.91137E-12
CS6	-56.5446	0	26.9954	14.9771
CS7	-1.3476E-11	-5.881E-12	-6.5009E-12	-7.8922E-12
CC1	0.002747	0	0.010349	0.001865
CC2	0	3.18928E-07	-3.0441E-07	0
CC3	-0.000348	0.000319	0.00024	0.000565
CC4	1.22123E-08	-7.7532E-08	-2.7144E-08	-5.4438E-08
CC5	0.12112	0.011894	0.013248	0.009236
CC6	1.04027E-12	-6.2266E-13	-2.0518E-12	0
CC7	-1.2401E-05	-7.0628E-06	-1.6538E-05	6.0269E-06
CC8	0	0	8.20869E-13	0
CC9	-3.758E-14	606235E-14	1.97598E-14	3.89425E-14
CC10	0.030056	0.023121	0.0265	0.01704
CC11	0	0	-0.271026	0.244274
CC12	0.002138	0.001103	0.006368	0.007323
CC13	-12.8674	-13.16522	-18.271	-10.1285

C6.8.3 Heating Factor. The heating factor for the surfaces in the zone shall be calculated using Equation C-16.

$$HEAT = 0.007669 \times [HLU + HLUO + HLXUO + HLM + HLG + HLS + HLC] \quad \text{(C-16)}$$

where

HLU = $Area_{opaque} \times U_{ow} \times [HU1 \times HDD50 + HU2 \times (VS \times HDD65)^2]$

HLUO = $Area_{grosswall} \times UO \times [HUO1 \times HDD50 + HUO2 \times HDD65 + HUO3 \times EA_H \times VS \times HDD65]$

HLXUO = $Area_{grosswall} \times \{(1/UO) \times [HXUO1 \times EA_H \times (VS \times HDD50)^2 + HXUO2 \times EA_H \times (VS \times HDD65)^2] + (1/UO2) \times [HXUO3 \times EA_H^2 \times VS \times HDD65]\}$

HLM = $Area_{opaque} \times SHMC \times [HM1 + HM2 \times G \times UO \times HDD65 + HM3 \times G2 \times EA_H^2 \times VS \times HDD50 + HM4 \times UO \times EA_H \times VS \times HDD65 + HM5 \times UO \times HDD50 + HM6 \times EA_H \times (VS \times HDD65)^2 + HM7 \times EA_H^2 \times VS \times HDD65/UO]$

HLG = $Area_{grosswall} \times \{G \times [HG1 \times HDD65 + HG2 \times UO \times HDD65 + HG3 \times EA_H \times VS \times HDD65 + HG4 \times EA_H^2 \times VS \times HDD50] \times G^2 \times [HG5 \times HDD65 + HG6 \times EA_H^2 \times VS \times HDD65]\}$

HLS = $Area_{grosswall} \times \{EA_H \times [HS1 \times VS \times HDD65 + HS2 \times (VS \times HDD50)^2] + EA_H^2 \times [HS3 \times VS \times HDD50 + HS4 \times VS \times HDD65]\}$

HLC = $Area_{grosswall} \times [HC1 + HC2 \times HDD65 + HC3 \times HDD652 + HC4 \times VS2 + HC5 \times VS \times HDD50 + HC6 \times VS \times HDD65 + HC7 \times (VS \times HDD50)^2]$

where

VS = annual average daily incident solar energy on surface

SHMC = sum of the HMC from Equation C-12 for each *mass wall* in the zone

EA_H = effective solar aperture fraction for zone calculated using Equation C-17.

$$EA_H = \frac{\sum SA_H}{Area_{grosswall}} \quad \text{(C-17)}$$

$\sum SA_h$ = the sum of SA_h from Equation C-7 for all *vertical fenestration* in the zone.

The coefficients used in the above equations depend on the *orientation* of the surface and shall be found in Table C6.8.3. Terms not defined for Equation C-16 are found under Equation C-14.

TABLE C6.8.3 Cooling Coefficients for the Exterior Wall Equation

	Orientation of Surface			
Variable	North	East	South	West
HU1	0.0006203	0.007691	0.006044	0.006672
HU2	-1.3587E-12	-5.7162E-13	-2.69E-13	-4.3566E-13
HM1	0.531005	0.545732	0.837901	0.616936
HM2	0.000152	0.000107	0.000208	0.00015
HM3	-5.3183E-07	-1.0619E-07	-6.8253E-07	-2.6457E-07
HM4	-7.7381E-07	-1.4787E-06	2.11938E-06	-4.5783E-07
HM5	-0.000712	-0.000484	-0.001042	-0.000625
HM6	3.34859E-13	4.95762E-14	7.7019E-14	7.37105E-14
HM7	2.39071E-07	2.75045E-07	-3.8989E-07	0
HUO1	0.004943	0.008683	0.009028	0.008566
HUO2	0.013686	0.011055	0.010156	0.01146
HUO3	-1.1018E-05	-8.6896E-06	-7.3232E-06	-8.9867E-06
HXUO1	1.2694E-12	7.85644E-14	-2.8202E-13	3.04904E-14
HXUO2	-7.3058E-13	-8.109E-14	7.45599E-14	-7.4718E-14
HXUO3	1.9709E-07	1.94026E-07	9.87587E-08	1.95776E-07
HG1	-0.0001051	-0.000983	-0.000981	-0.000948
HG2	-0.001063	-0.00093	-0.000815	-0.000975
HG3	2.99013E-06	2.62269E-06	2.4188E-06	2.49976E-06
HG4	7.49049E-07	-1.1106E-06	-2.1669E-06	-8.5605E-07
HG5	0.000109	0.0000093431	9.75523E-05	8.62389E-05
HG6	-5.5591E-07	-3.158E-07	-2.61E-07	-2.9133E-07
HS1	-2.1825E-05	-2.0922E-05	-2.1089E-05	-2.0205E-05
HS2	3.39179E-12	1.905E-12	1.48388E-12	2.18215E-12
HS3	-6.5325E-06	-2.2341E-05	-1.8473E-05	-2.4049E-05
HS4	2.23087E-05	2.41331E-05	2.45412E-05	2.30538E-05
HC1	-0.106468	-5.19297	-3.66743	-5.29681
HC2	0.00729	0.007684	0.007175	0.007672
HC3	-2.976E-07	-3.0784E-07	-2.6419E-07	-3.0713E-07
HC4	2.01569E-06	6.3035E-06	3.32112E-06	6.43491E-06
HC5	1.29061E-05	4.77552E-06	3.25089E-06	4.83233E-06
HC6	-1.2859E-05	-6.1854E-06	-4.6309E-06	-6.251E-06
HC7	2.75861E-12	8.20051E-13	43.38148E-13	8.09106E-13

C6.9 Skylights in the Exterior Building Envelope. HEAT and COOL shall be calculated for *skylights* in *nonresidential conditioned* and *residential conditioned* zones using Equations C-18 and C-19.

$$HEAT = Area_{sky} \times HDD65 \times 0.66 \times (H_2 \times U_{sky} + H_3 \times 1.163 \times SHGC) \quad \text{(C-18)}$$

$$COOL = Area_{sky} \times C_2 \times CDD50 \times 0.093 \times SHGC \quad \text{(C-19)}$$

where

$Area_{sky}$ = *fenestration* area of the *skylight* assembly

SHGC = the *solar heat gain coefficient* of the *skylight* assembly

U_{sky} = *U-factor* of *skylight* assembly

The coefficients used in the equations depend on the space type and shall be taken from Table C6.9.

TABLE C6.9 Heating and Cooling Coefficients for Skylights

Coefficient	Nonresidential	Residential
C2	1.09E-02	1.64E-02
H2	2.12E-04	2.91E-04
H3	1.68E-04	2.96E-04

C6.10 Calculations for Other Exterior and Semi-Exterior Surfaces. For all exterior and semi-exterior surfaces not covered in C6.8 and C6.9, the cooling factor, COOL, and heating factor, HEAT, shall be calculated using the procedure in this subsection.

C6.10.1 U-Factor for Below-Grade Walls. The effective *U-factor* of *below-grade walls* shall be calculated using Equation C-20. R_{soil} shall be selected from Table C6.10.1 based on the average depth of the bottom of the wall below the surface of the ground.

$$U\text{-factor} = 1 / ((1/C\text{-factor}) + 0.85 + R_{soil})$$

where

R_{soil} = effective R-value of the soil from Table C6.10.1

C6.10.2 Adjustment for Other Protected Elements of the Exterior Envelope. The adjusted *U-factor* for *exterior envelope surfaces*, which are protected from outdoor conditions by crawlspaces, attics, or parking garages with natural or mechanical ventilation, shall be adjusted using Equation C-21 before calculating HEAT and COOL.

$$U_{adj} = 1 / ((1 / \text{U-factor}) + 2)$$

C6.10.3 Calculation of COOL and HEAT. COOL and HEAT shall be calculated for each surface using Equations C22 and C-23 and coefficients from Table C6.10.2, which depend on surface classification and *space-conditioning category*.

$$COOL = Size \times Factor \times 0.08 \times (Ccoef1 \times CDD50 + Ccoef2)$$

$$HEAT = Size \times Hcoef \times Factor \times HDD65 \times 0.66$$

where

Size = area of surface or length of exposed *slab-on-grade floor perimeter in the building*

(C-21)

Ccoef1, Ccoef2 = coefficients, from Table C6.10.2

Hcoef = coefficient from Table C6.10.2

Factor = *U-factor* except U_{adj} calculated using Equation C-21 for protected surfaces and for *slab-on-grade floors*, perimeter *F-factor*

(C-22)

TABLE C6.10.1 Effective R-Value of Soil for Below-Grade Walls

Depth	R_{soil} (h·ft²·°F/Btu)
1 ft	0.86
2 ft	1.6
3 ft	2.2
4 ft	2.9
5 ft	3.4
6 ft	4.0
7 ft	4.5
8 ft	5.1
9 ft	5.6
10 ft	6.1

TABLE C6.10.2 Heating and Cooling Coefficients for Other Exterior and Semi-Exterior Surfaces

Building Envelope Classification	Exterior						Semi-Exterior		
Space-Conditioning Type	Nonresidential			Residential			All		
Surface Type	Ccoef1	Ccoef2	HCoef	Ccoef1	Ccoef2	HCoef	Ccoef1	Ccoef2	HCoef
Roof	0.001153	5.56	2.28E-04	0.001656	9.44	3.37E-04	0	0	8.08E-05
Wall, Above-Grade, and Opaque Doors	6.04E-04	0	2.28E-04	1.18E-03	0	3.37E-04	0	0	7.56E-05
Wall, Below-Grade	2.58E-04	0	2.29E-04	6.80E-04	0	3.35E-04	NA	0	7.85E-05
Mass Floor	6.91E-04	0	2.39E-04	1.01E-03	0	3.60E-04	0	0	7.14E-05
Other Floor	7.09E-04	0	2.43E-04	9.54E-04	0	3.66E-04	0	0	7.14E-05
Slab-on-Grade Floor	0	0	2.28E-04	0	0	3.37E-04	0	0	6.80E-05
Vertical Fenestration	NA	0	NA	NA	0	NA	0	0	7.56E-05
Skylights	NA	0	NA	NA	0	NA	0	0	8.08E-05

➡ **NORMATIVE APPENDIX D Reserved.**

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(This appendix is not part of this code. It is merely informative and does not contain requirements necessary for conformance to the code. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE APPENDIX E

INFORMATIVE REFERENCES

This appendix contains informative references for the convenience of users of this code and to acknowledge source documents when appropriate. Some documents are also included in Section 12 – Normative References because there

AABC
Associated Air Balance Council
1518 K Street Northwest, Suite 503
Washington, DC 20005
aabchg@aol.com

ASHRAE
1791 Tullie Circle, N.E.
Atlanta, GA 30329
Toll-free for Customer Service: (800) 527-4723 (U.S. and Canada only)
Phone: (404) 636-8400
Fax: (404) 321-5478

BLAST
Building Systems Laboratory
University of Illinois
1206 West Green Street
Urbana, Illinois 61801
http://www.bso.uiuc.edu/BLAST/index.html

DOE-2
Building Energy Simulation news
http://simulationresearch.lbl.gov/un.html

MICA
Midwest Insulation Contractors Association
16712 Elm Circle
Omaha, NE 68130
http://www.micainsulation.org

National Institute for Building Standards
1090 Vermont Avenue, NW, Ste. 700
Washington, DC 20005-4905
Phone: (202) 289-7800

NEBB
National Environmental Balancing Bureau
8575 Grovemont Circle
Gaithersburg, MD 20877
http://www.nebb.org

SMACNA
Sheet Metal & Air Conditioning Contractors' National Association
4201 Lafayette Center Drive
Chantilly, VA 20151
info@smacna.org
http://www.smacna.org

TMY2 Data
National Renewable Energy Laboratory
NREL/RReDC
Attn: Pamela Gray-Hann
1617 Cole Blvd., MS-1612
Golden, Colorado, USA 80401
http://rredc.nrel.gov/solar/old_data/nsrdb/tmy2/

WYEC2 Data
American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
ASHRAE Bookstore
1791 Tullie Circle, NE
Atlanta, GA 30329-2305
(T) 404-636-8400
(F) 404-321-5478
http://resourcecenter.ashrae.org/store/ashrae/

IWEC Data
American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
ASHRAE Bookstore
1791 Tullie Circle, NE
Atlanta, GA 30329-2305
(T) 404-636-8400
(F) 404-321-5478

Subsection	Reference	Title/Source
5.9	ASHRAE Guideline 0 – 2005	The Commissioning Process
5.9	NIBS Guideline 3 – 2006	Exterior Enclosure Technical Requirements for Commissioning Process
6.4.2	2001 ASHRAE Handbook—Fundamentals	ASHRAE
6.4.4.1.1	MICA Insulation Standards - 1999	National commercial and industrial insulation standards
6.4.4.2.1	SMACNA Duct Construction Standards - 1995	HVAC duct construction standards, metal and flexible
6.4.4.2.2	SMACNA Duct Leakage Test Procedures - 1985	HVAC Air Duct Leakage Test Manual
6.7.2.3.1	NEBB Procedural Standards - 1999	Procedural standards for building systems commissioning
6.7.2.3.1	AABC 2002	Associated Air Balance Council Test and Balance procedures
6.7.2.3.1	ASHRAE Standard 111 - 1988	Practices for Measurement, Testing, Adjusting and Balancing of Building Heating, Ventilation, Air-Conditioning and Refrigeration
6.7.2.2	ASHRAE Guideline 4 - 1993	Preparation of Operating and Maintenance Documentation for Building Systems
6.7.2.4	ASHRAE Guideline 1 - 1996	The HVAC Commissioning Process
6.9	NIBS Guideline 3 – 2006	Exterior Enclosure Technical Requirements for Commissioning Process
7.4.1 and 7.5	2003 ASHRAE Handbook—HVAC Applications	Chapter 49, Service Water Heating
11.2.1	DOE-2	Support provided by Lawrence Berkeley National Lab at the referenced web site
11.2.1	BLAST	University of Illinois
11.2.2	IWEC	International Weather for Energy Calculations
11.2.2	TMY 2 Data	Typical Meteorological Year

(This appendix is not part of this code. It is merely informative and does not contain requirements necessary for conformance to the code. It has not been processed according to the ANSI requirements for a standard and may contain material that has not been subject to public review or a consensus process. Unresolved objectors on informative material are not offered the right to appeal at ASHRAE or ANSI.)

INFORMATIVE APPENDIX F

ADDENDA DESCRIPTION INFORMATION

ASHRAE/IESNA Standard 90.1-2004 incorporates ANSI/ASHRAE/IESNA Standard 90.1-2001 and Addenda a, b, c, d, e, g, h, i, j, k, m, n, o, p, q, r, s, t, u, x, y, z, aa, ab, ac, ae, ag, ah, ai, ak, al, and am to ANSI/ASHRAE/IESNA Standard 90.1-2001. Table F-1 lists each addendum and describes the way in which the text is affected by thechange. Table F-2 states the ASHRAE and ANSI approval dates.

TABLE F-1 Addenda to ANSI/ASHRAE/IESNA Standard 90.1-2001, Changes Identified

Addenda to 90.1-2001	Sections Affected	Description of Changes a
90.1a	4. Administration and Enforcement	Addendum deletes Section 4.4.7 in its entirety. Requirements for *transformers* were deleted from a prior draft of the standard, and Section 4.4.7 was inadvertently not deleted at the same time the transformer requirements were deleted. Without the transformer requirements in Section 8, or any sort of indication as to what transformers were to be labeled, the requirement for labeling transformers with their "energy-efficiency level" in Section 4.4.7 became meaningless or confusing.
90.1b	6. Heating, Ventilating, and Air Conditioning	Change to 6.2.1, Mechanical Equipment Efficiency, relates to the certification program for product performance verification.
90.1c	6. Heating, Ventilating, and Air Conditioning	This change modifies Table 6.2.4.3B, Duct Seal Levels, with regard to pressure-sensitive tape.
90.1d	6. Heating, Ventilating, and Air Conditioning	This change to Table 6.2.1D establishes minimum efficiency standards for single-package vertical air-conditioners (SPVAC) and heat pumps (SPVHP). It is consistent with DOE's decision to regulate SPVUs under EPACT.
90.1e	11. Energy Cost Budget Method	New Informative Appendix G is for use in rating the performance of building designs. This is an informative appendix because it is not to be included as part of the minimum requirements to comply with code. The appendix parallels Section 11, on which it is based, and is an attempt at providing a generic method that can be referenced by any rating agency.
90.1g	Tables 9.3.1.1 and 9.3.1.2 Lighting Power Densities Density	This replacement of Tables 9.3.1.1 and 9.3.1.2 of 90.1-2001 including the Lighting Power (LPD) values represents a complete review and update of the inputs to the space and building models used to derive these values.
90.1h	12. Normative References and Normative Appendix A	This addendum updates the references in Section 12 and the test procedure references in Sections A9.3.1 and A9.3.2.
90.1i	6. Heating, Ventilating, and Air Conditioning	This addendum revises Tables 6.2.1A and 6.2.1B to reflect newly adopted DOE efficiency standards for single-phase air conditioners and heat pumps less than 65,000 Btu/h.
90.1j	9. Lighting	This addendum applies to the exceptions to 9.3.1, Interior Lighting Power, specifically exception (n), athletic playing areas.
90.1k	6. Heating, Ventilating, and Air Conditioning	Change to 6.2.3.1.1, General, relates to zone and loop controllers.
90.1m	7. Service Water Heating	Addendum added requirement for heat pump pool heaters to Table 7.2.2.
90.1n	6. Heating, Ventilating, and Air Conditioning	Addendum provides detailed explanations of control means to clarify the intent of supplemental heater control requirements in 6.1.3 (g), Simplified Approach Option for HVAC Systems.
90.1o.	6. Heating, Ventilating, and Air Conditioning	This addendum deletes exception (d) in Section 6.3.1.

TABLE F-1 (*continued*) Addenda to ANSI/ASHRAE/IESNA Standard 90.1-2001, Changes Identified

Addenda to 90.1-2001	Sections Affected	Description of Changes a
90.1p	11. Energy Cost Budget Method	This addendum adds a new Section 11.2.1.4 containing a reference to ASHRAE Standard 140.
90.1q	9. Lighting	This addendum revises the exterior lighting requirements in Sections 9.2.1.3 and 9.3.2 as well as Table 9.3.2.
90.1r	6. Heating, Ventilating, and Air Conditioning	This addendum adds requirements for return duct insulation to Table 6.2.4.2B.
90.1s	6. Heating, Ventilating, and Air Conditioning	This addendum revises exceptions (g) and (i) in Section 6.3.6.1.
90.1t	9. Lighting	Change to the exceptions to the automatic control device requirement for building lighting in exceptions to 9.2.1.1.
90.1u	6. Heating, Ventilating, and Air Conditioning	Change to Tables 6.3.1.1.3.A and 6.3.1.1.3B to add dew point or mixing ration with temperature shutoff control types and required high-limit values for these type of controls.
90.1x	6. Heating, Ventilating, and Air Conditioning	Change to Sections 6.1.3i and 6.2.3.2, and the addition of a new Section 6.2.3.3.5, Ventilation Fan Controls.
90.1y	6. Heating, Ventilating, and Air Conditioning	Change to Section 6.3.3.2.1, Part-Load Fan Power Limitation, to reduce the requirement for VAV fans with motors from 30 hp to 15 hp.
90.1z	6. Heating, Ventilating, and Air Conditioning	Change to the Exception to 6.2.1.
90.1aa	6. Heating, Ventilating, and Air Conditioning and 12. Normative	Change to update all of the normative references in Section 12 including the test procedure references in Tables 6.2.1A and 6.2.1B to reflect the newly published ARI Standard References 210/240-2003.
90.1ab	6. Heating, Ventilating, and Air Conditioning	Change to exceptions to 6.3.6.1 (d), Exhaust Air Energy Recovery, relating to commercial kitchen hoods.
90.1ac	11. Energy Cost Budget Method	Change to Sections 11.3.1, exceptions to 11.3.6, 11.3.8, 11.3.9, Note 7 of Table 11.4.3A, and Section 11.4.3.
90.1ae	9. Lighting	Change to Section 9.2.1.1, Space Control.
90.1ag	Table 9.3.1.2	This revision of the retail “sales area” LPD value is a correction of the previously approved Addendum g to the 90.1-2001 standard. When the initial table of space-by-space method LPDs was prepared for Addendum g public review, the “Retail Sales area” was inadvertently left at the previous 90.1-2001 value of 2.1 W/ft^2 (23 W/m^2). The correct value produced by the applicable space type models is 1.7 W/ft^2 (18 W/m^2), which should have been included in Addendum g to 90.1-2001. This addendum seeks to correct this oversight.
90.1ah	Tables D-1 and D-3	This addendum is intended to add new weather data for nine new locations, including the District of Columbia (to remedy an earlier omission) plus six locations in the U.S. Territories and a new location in the Philippines. These additions do not impact the stringency of the standard but simply increase its usability.
90.1ai	9. Lighting	Change to Section 9.2.3, Exit Signs, to require a maximum of 5 watt per face of exit signs.
90.1ak	Table 6.2.1G, Performance Requirements for Heat Rejection Equipment, and Section 6.2.1	Change to Table 6.2.1G to add requirements for cooling towers to be tested to CTI test procedures and to update the corresponding references in Section 6.2.1.
90.1al	Informative Appendix E, Informative References	Change to Appendix E to update references related to building energy simulation software and annual weather data.
90.1am	5. Building Envelope and 6. HVAC	Changes to Sections 5 and 6 plus Appendices B and D to reduce the climatic data tables from 26 to 8 climate zones. This is consistent with the DOE and IECC climate tables.

[a] These descriptions may not be complete and are provided for information only.

TABLE F-2 Addenda to ANSI/ASHRAE/IESNA Standard 90.1-2001, Approval Dates

Addenda to 90.0-2001	ASHRAE Standards Committee Approval Date	ASHRAE Board of Directors Approval Date	ANSI Approval Date	IESNA Board of Directors Approval Date
90.1a	January 25, 2003	January 30, 2003	April 3, 2003	December 7, 2002
90.1b	June 22, 2002	June 27, 2002	July 30, 2002	June 2, 2002
90.1c	June 22, 2002	June 27, 2002	July 30, 2002	June 2, 2002
90.1d	June 22, 2002	June 27, 2002	July 30, 2002	June 2, 2002
90.1e	January 24, 2004	January 29, 2004	March 31, 2004	December 6, 2003
90.1g	June 28, 2003	July 3, 2003	August 6, 2003	March 3, 2003
90.1h	October 5, 2003	January 29, 2004	February 25, 2004	December 6, 2004
90.1i	June 28, 2003	July 3, 2003	August 6, 2003	August 3, 2003
90.1j	June 28, 2003	July 3, 2003	August 6, 2003	August 3, 2003
90.1k	September 17, 2002	October 14, 2002	December 17, 2002	December 7, 2002
90.1m	January 25, 2003	January 30, 2003	April 3, 2003	December 7, 2002
90.1n	June 28, 2003	July 3, 2003	September 25, 2003	August 3, 2003
90.1o	October 5, 2003	January 29, 2004	February 25, 2004	December 6, 2004
90.1p	October 5, 2003	January 29, 2004	February 25, 2004	December 6, 2004
90.1q	June 26, 2004	July 1, 2004	July 1, 2004	July 25, 2004
90.1r	October 5, 2003	January 29, 2004	February 25, 2004	December 6, 2004
90.1s	October 5, 2003	January 29, 2004	February 25, 2004	December 6, 2004
90.1t	April 28, 2004	July 1, 2004	July 1, 2004	March 30, 2004
90.1u	June 26, 2004	July 1, 2004	July 1, 2004	July 25, 2004
90.1x	May 10, 2004	July 1, 2004	August 5, 2004	March 30, 2004
90.1y	April 28, 2004	July 1, 2004	July 1, 2004	March 30, 2004
90.1z	April 28, 2004	July 1, 2004	July 1, 2004	March 30, 2004
90.1aa	April 28, 2004	July 1, 2004	July 1, 2004	March 30, 2004
90.1ab	April 28, 2004	July 1, 2004	July 1, 2004	March 30, 2004
90.1ac	June 26, 2004	July 1, 2004	July 1, 2004	July 25, 2004
90.1ae	June 26, 2004	July 1, 2004	July 1, 2004	July 25, 2004
90.1ag	April 28, 2004	July 1, 2004	July 1, 2004	March 30, 2004
90.1ah	April 28, 2004	July 1, 2004	July 1, 2004	March 30, 2004
90.1ai	June 26, 2004	July 1, 2004	July 1, 2004	July 25, 2004
90.1al	June 26, 2004	July 1, 2004	July 1, 2004	July 25, 2004
90.1am	June 26, 2004	July 1, 2004	July 1, 2004	July 25, 2004

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INFORMATIVE APPENDIX G

PERFORMANCE RATING METHOD

G1 GENERAL

G1.1 Performance Rating Method Scope. This building performance rating method is a modification of the Energy Cost Budget (ECB) Method in Section 11 and is intended for use in rating the energy *efficiency* of building designs that exceed the requirements of this code. This appendix does NOT offer an alternative compliance path for minimum standard compliance; that is the intent of Section 11, Energy Cost Budget Method. Rather, it is provided for those wishing to use the methodology developed for this code to quantify performance that substantially exceeds the requirements of this code. It may be useful for evaluating the performance of all *proposed designs*, including *alterations* and *additions* to *existing buildings*, except designs with no mechanical systems.

G1.2 Performance Rating. This performance rating method requires conformance with the following provisions:

All requirements of 5.4, 6.4, 7.4, 8.4, 9.4, and 10.4 are met. These sections contain the mandatory provisions of the code, and are prerequisites for this rating method. The improved performance of the proposed building design is calculated in accordance with provisions of this appendix using the following formula:

Percentage improvement = 100 × *(Baseline building performance - Proposed building performance) / Baseline building performance*

Notes:

1. Both the *proposed building performance* and the *baseline building performance* shall include all end-use load components, such as receptacle and process loads.
2. Neither the *proposed building performance* nor the *baseline building performance* are predictions of actual energy consumption or costs for the *proposed design* after construction. Actual experience will differ from these calculations due to variations such as occupancy, building operation and maintenance, weather, energy use not covered by this procedure, changes in energy rates between design of the building and occupancy, and the precision of the calculation tool.

G1.3 Trade-Off Limits. When the proposed modifications apply to less than the whole building, only parameters related to the systems to be modified shall be allowed to vary. Parameters relating to unmodified existing conditions or to future building components shall be identical for determining both the *baseline building performance* and the *proposed building performance*. Future building components shall meet the prescriptive requirements of Sections 5.5, 6.5, 7.5, 9.5, and 9.6.

G1.4 Documentation Requirements. Simulated performance shall be documented, and documentation shall be submitted to the *rating authority*. The information submitted shall include the following:

(a) Calculated values for the *baseline building performance*, the *proposed building performance*, and the percentage improvement.

(b) A list of the energy-related features that are included in the design and on which the performance rating is based. This list shall document all energy features that differ between the models used in the *baseline building performance* and *proposed building performance* calculations.

(c) Input and output report(s) from the *simulation program* or compliance software including a breakdown of energy usage by at least the following components: lights, internal equipment loads, service water heating equipment, space heating equipment, space cooling and heat rejection equipment, fans, and other HVAC equipment (such as pumps). The output reports shall also show the amount of time any loads are not met by the HVAC system for both the *proposed design* and *baseline building design*.

(d) An explanation of any error messages noted in the *simulation program* output.

G2 SIMULATION GENERAL REQUIREMENTS

G2.1 Performance Calculations. The *proposed building performance* and *baseline building performance* shall be calculated using the following:

(a) the same *simulation program*,

(b) the same weather data, and

(c) the same energy rates.

G2.2 Simulation Program. The *simulation program* shall be a computer-based program for the analysis of energy consumption in buildings (a program such as, but not limited to, DOE-2, BLAST, or EnergyPlus). The *simulation program* shall include calculation methodologies for the building components being modeled. For components that cannot be modeled by the *simulation program*, the exceptional calculation methods requirements in Section G2.5 may be used.

G2.2.1 The *simulation program* shall be approved by the *rating authority* and shall, at a minimum, have the ability to explicitly model all of the following:

(a) 8,760 hours per year;

(b) hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat setpoints, and HVAC system operation, defined separately for each day of the week and holidays;

(c) thermal mass effects;

(d) ten or more thermal zones;

(e) part-load performance curves for mechanical equipment;

(f) capacity and *efficiency* correction curves for mechanical heating and cooling equipment;

(g) air-side economizers with integrated control;

(h) *baseline building design* characteristics specified in G3.

G2.2.2 The *simulation program* shall have the ability to either (1) directly determine the *proposed building performance* and *baseline building performance* or (2) produce hourly reports of energy use by an energy source suitable for determining the *proposed building performance* and *baseline building performance* using a separate calculation engine.

G2.2.3 The *simulation program* shall be capable of performing design load calculations to determine required HVAC equipment capacities and air and water flow rates in accordance with generally accepted engineering standards and handbooks (for example, ASHRAE Handbook—*Fundamentals*) for both the *proposed design* and *baseline building design*.

G2.3 Climate Data. The *simulation program* shall perform the simulation using hourly values of climate data, such as temperature and humidity from representative climate data, for the site in which the *proposed design* is to be located. For cities or urban regions with several climate data entries, and for locations where weather data are not available, the designer shall select available weather data that best represent the climate at the construction site. The selected weather data shall be approved by the *rating authority*.

G2.4 Energy Rates. Annual energy costs shall be determined using either actual rates for purchased energy or state average energy prices published by DOE's Energy Information Administration (EIA) for commercial building customers, but rates from different sources may not be mixed in the same project.

Note: The above provision allows users to gain credit for features that yield load management benefits. Where such features are not present, users can simply use state average unit prices from EIA, which are updated annually and readily available on EIA's web site (http://www.eia.doe.gov/).

Exception to G2.4: On-site renewable energy sources or site-recovered energy shall not be considered to be purchased energy and shall not be included in the *proposed building performance*. Where on-site renewable or site-recovered sources are used, the *baseline building performance* shall be based on the energy source used as the backup energy source or on the use of electricity if no backup energy source has been specified.

G2.5 Exceptional Calculation Methods. Where no simulation program is available that adequately models a design, material, or device, the *rating authority* may approve an exceptional calculation method to demonstrate above-standard performance using this method. Applications for approval of an exceptional method shall include documentation of the calculations performed and theoretical and/or empirical information supporting the accuracy of the method.

G3 Calculation of the Proposed and Baseline Building Performance

G3.1 Building Performance Calculations. The simulation model for calculating the proposed and *baseline building performance* shall be developed in accordance with the requirements in Table G3.1.

G3.1.1 Baseline HVAC System Type and Description. HVAC systems in the *baseline building design* shall be based on usage, number of floors, conditioned floor area, and heating source as specified in Table G3.1.1A and shall conform with the system descriptions in Table G3.1.1B.

Exceptions to G3.1.1:

(a) Use additional system type(s) for non-predominant conditions (i.e., residential/nonresidential or heating source) if those conditions apply to more than 20,000 ft^2 of conditioned floor area.

(b) If the baseline HVAC system type is 5, 6, 7, or 8, use separate single-zone systems conforming with the requirements of System 3 or System 4 (depending on building heating source) for any spaces that have occupancy or process loads or schedules that differ significantly from the rest of the building. Peak thermal loads that differ by 10 Btu/h-ft^2 or more from the average of other spaces served by the system or schedules that differ by more than 40 equivalent full-load hours per week from other spaces served by the system are considered to differ significantly. Examples where this exception may be applicable include, but are not limited to, computer server rooms, natatoriums, and continually occupied security areas.

(c) If the baseline HVAC system type is 5, 6, 7, or 8, use separate single-zone systems conforming with the requirements of System 3 or System 4 (depending on building heat source) for any zones having special pressurization relationships, cross-contamination requirements, or code-required minimum circulation rates.

G3.1.1.1 Purchased Heat. For systems using purchased hot water or steam, hot water or steam costs shall be based on actual utility rates, and on-site boilers shall not be modeled in the *baseline building design*.

G3.1.2 General Baseline HVAC System Requirements. HVAC systems in the *baseline building design* shall conform with the general provisions in this section.

G3.1.2.1 Equipment Efficiencies. All HVAC equipment in the *baseline building design* shall be modeled at the minimum *efficiency* levels, both part load and full load, in accordance with Section 6.4.Where *efficiency* ratings, such as EER and COP, include fan energy, the descriptor shall be broken down into its components so that supply fan energy can be modeled separately.

G3.1.2.2 Equipment Capacities. The equipment capacities for the *baseline building design* shall be based on sizing runs for each orientation (per Table G3.1 No. 5a) and shall be oversized by 15% for cooling and 25% for heating; i.e., the ratio between the capacities used in the annual simulations and the capacities determined by the sizing runs shall be 1.15 for cooling and 1.25 for heating. Unmet load hours for the *proposed design* or *baseline building designs* shall not exceed 300 (of the 8,760 hours simulated), and unmet load hours for the *proposed design* shall not exceed the number of unmet load hours for the *baseline building design* by more than 50. If unmet load hours in the *proposed design* exceed the unmet load hours in the *baseline building* by more than 50, simulated capacities in the *baseline building* shall be decreased incrementally and the building resimulated until the unmet load hours are within 50 of the unmet load hours of the *proposed design*. If unmet load hours for the *proposed design* or *baseline building design* exceed 300, simulated capacities shall be increased incrementally, and the building with unmet loads resimulated until unmet load hours are reduced to 300 or less. Alternatively, unmet load hours exceeding these limits may be accepted at the discretion of the *rating authority* provided that sufficient justification is given indicating that the accuracy of the simulation is not significantly compromised by these unmet loads.

G3.1.2.2.1 Sizing Runs. Weather conditions used in sizing runs to determine *baseline* equipment capacities may be based either on hourly historical weather files containing typical peak conditions or on design days developed using 99.6% heating design temperatures and 1% dry-bulb and 1% wet-bulb cooling design temperatures.

G3.1.2.3 Preheat Coils. If the HVAC system in the *proposed design* has a preheat coil and a preheat coil can be modeled in the *baseline* system, the *baseline* system shall be modeled with a preheat coil controlled in the same manner as the *proposed design*.

G3.1.2.4 Fan System Operation. Supply and return fans shall operate continuously whenever spaces are occupied and shall be cycled to meet heating and cooling loads during unoccupied hours. If the supply fan is modeled as cycling and fan energy is included in the energy-efficiency rating of the equipment, fan energy shall not be modeled explicitly.

G3.1.2.5 Ventilation. Minimum *outdoor air* ventilation rates shall be the same for the *proposed* and *baseline building designs*.

Exception to G3.1.2.5: When modeling demand-control ventilation in the *proposed design* when its use is not required by 6.4.3.8.

G3.1.2.6 Economizers. Outdoor air economizers shall not be included in *baseline* HVAC Systems 1 and 2. Outdoor air economizers shall be included in *baseline* HVAC Systems 3 and 4 as specified in Table G3.1.2.6A based on building conditioned floor area, whether the zone served is an interior or perimeter zone, and climate. *Outdoor air* economizers shall be included in *baseline* HVAC Systems 5 through 8 based on climate as specified in Table G3.1.2.6B. Any zone having more than half of its floor area more than 15 ft from a glazed exterior wall is considered an interior zone for purposes of applying Tables G3.1.2.6A and B.

Exceptions to G3.1.2.6: Economizers shall not be included for systems meeting one or more of the exceptions listed below.

(a) Systems that include gas-phase air cleaning to meet the requirements of 6.1.2 of ANSI/ASHRAE Standard 62. This exception shall be used only if the system in the *proposed design* does not match *building design*.

(b) Where the use of *outdoor air* for cooling will affect supermarket open refrigerated casework systems. This exception shall only be used if the system in the *proposed design* does not use an economizer. If the exception is used, an economizer shall not be included in the baseline *building design*.

G3.1.2.7 Economizer High-Limit Shutoff. The high-limit shutoff shall be a dry-bulb switch with setpoint temperatures in accordance with the values in Table G3.1.2.6C.

G3.1.2.8 Design Air Flow Rates. System design supply air flow rates for the *baseline building design* shall be based on a supply-air-to-room-air temperature difference of 20°F. If return or relief fans are specified in the *proposed design*, the *baseline building design* shall also be modeled with fans serving the same functions and sized for the *baseline* system supply fan air quantity less the minimum *outdoor air*, or 90% of the supply fan air quantity, whichever is larger.

G3.1.2.9 Supply Fan Power. System fan electrical power for supply, return, exhaust, and relief (excluding power to fan-powered VAV boxes) shall be calculated using the following formulas:

$$P_{fan} = 746 / (1 - e^{[-0.2437839 \times \ln(\text{bhp}) - 1.685541]}) \times \text{bhp}$$

where

P_{fan} = electric power to fan motor (watts) and

bhp = brake horsepower of *baseline* fan motor from Table G3.1.2.9, where cfm represents design supply flow rate.

Exception to G3.1.2.9: If systems in the *proposed design* require air filtering systems with pressure drops in excess of 1 in. w.c. when filters are clean, the allowable fan system power in the *baseline design* system serving the same space may be increased using the following pressure credit:

$$\text{Pressure Credit (watts)} = \text{CFM}_{\text{filter}} * (\text{Sp}_{\text{filter}} - 1)/4.984$$

where

CFM_{filter} = supply air volume of the proposed system with air filtration system in excess of 1 in.

Sp_{filter} = air pressure drop of the filtering system in w.g. when the filters are clean.

G3.1.2.10 Exhaust Air Energy Recovery. Individual fan systems that have both a design supply air capacity of 5000 cfm or greater and have a minimum outdoor air supply of 70% or greater of the design supply air quantity shall have an energy recovery system with at least 50% recovery effectiveness. Fifty percent energy recovery effectiveness shall mean a change in the enthalpy of the *outdoor air* supply equal to 50% of the difference between the *outdoor air* and return air at design conditions. Provision shall be made to bypass or control the heat-recovery system to permit air economizer operation, where applicable.

Exceptions to G3.1.2.10: If any of these exceptions apply, exhaust air energy recovery shall not be included in the *baseline building design*.

(a) Systems serving spaces that are not cooled and that are heated to less than 60°F.

(b) Systems exhausting toxic, flammable, or corrosive fumes or paint or dust. This exception shall only be used if exhaust air energy recovery is not used in the *proposed design*.

(c) Commercial kitchen hoods (grease) classified as Type 1 by NFPA 96. This exception shall only be used if exhaust air energy recovery is not used in the *proposed design*.

(d) Heating systems in climate zones 1 through 3.

(e) Cooling systems in climate zones 3c, 4c, 5b, 5c, 6b, 7, and 8.

(f) Where the largest exhaust source is less than 75% of the design *outdoor air* flow. This exception shall only be used if exhaust air energy recovery is not used in the *proposed design*.

(g) Systems requiring dehumidification that employ energy recovery in series with the cooling coil. This exception shall only be used if exhaust air energy recovery and series-style energy recovery coils are not used in the *proposed design*.

TABLE G3.1 Modeling Requirements for Calculating Proposed and Baseline Building Performance

No. Proposed Building Performance	Baseline Building Performance
1. Design Model	
(a) The simulation model of the *proposed design* shall be consistent with the design documents, including proper accounting of fenestration and opaque envelope types and areas; interior lighting power and controls; HVAC system types, sizes, and controls; and service water heating systems and controls. All end-use load components within and associated with the building shall be modeled, including, but not limited to, exhaust fans, parking garage ventilation fans, snow-melt and freeze-protection equipment, facade lighting, swimming pool heaters and pumps, elevators and escalators, refrigeration, and cooking. (b) All conditioned spaces in the *proposed design* shall be simulated as being both heated and cooled even if no heating or cooling system is to be installed, and temperature and humidity control set-points and schedules shall be the same for *proposed* and *baseline building designs*. (c) When the *performance rating method* is applied to buildings in which energy-related features have not yet been designed (e.g., a lighting system), those yet-to-be-designed features shall be described in the *proposed design* exactly as they are defined in the *baseline building design*. Where the space classification for a space is not known, the space shall be categorized as an office space.	The *baseline building design* shall be modeled with the same number of floors and identical conditioned floor area as the *proposed design*.
2. Additions and Alterations	
It is acceptable to predict performance using building models that exclude parts of the *existing building* provided that all of the following conditions are met: (a) Work to be performed in excluded parts of the building shall meet the requirements of Sections 5 through 10. (b) Excluded parts of the building are served by HVAC systems that are entirely separate from those serving parts of the building that are included in the building model. (c) Design space temperature and HVAC system operating set-points and schedules on either side of the boundary between included and excluded parts of the building are essentially the same. (d) If a declining block or similar utility rate is being used in the analysis and the excluded and included parts of the building are on the same utility meter, the rate shall reflect the utility block or rate for the building plus the *addition*.	Same as Proposed Design
3. Space Use Classification	
Usage shall be specified using the building type or space type lighting classifications in accordance with 9.5.1 or 9.6.1. The user shall specify the space use classifications using either the building type or space type categories but shall not combine the two types of categories. More than one building type category may be used in a building if it is a mixed-use facility. If space type categories are used, the user may simplify the placement of the various space types within the building model, provided that building-total areas for each space type are accurate.	Same as Proposed Design
4. Schedules	
Schedules capable of modeling hourly variations in occupancy, lighting power, miscellaneous equipment power, thermostat set-points, and HVAC system operation shall be used. The schedules shall be typical of the proposed building type as determined by the designer and approved by the *rating authority*. **HVAC Fan Schedules.** Schedules for HVAC fans shall run continuously whenever spaces are occupied and shall be cycled on and off to meet heating and cooling loads during unoccupied hours. **Exception:** Where no heating and/or cooling system is to be installed and a heating or cooling system is being simulated only to meet the requirements described in this table, heating and/or cooling system fans shall not be simulated as running continuously during occupied hours but shall be cycled on and off to meet heating and cooling loads during all hours.	Same as Proposed Design **Exception:** Schedules may be allowed to differ between *proposed design* and *baseline building design* when necessary to model nonstandard *efficiency* measures, provided that the revised schedules have the approval of the rating authority. Measures that may warrant use of different schedules include, but are not limited to, lighting controls, natural ventilation, demand control ventilation, and measures that reduce service water heating loads.

TABLE G3.1 (*continued*) Modeling Requirements for Calculating Proposed and Baseline Building Performance

No.	Proposed Building Performance	Baseline Building Performance
5. Building Envelope		
	All components of the *building envelope* in the *proposed design* shall be modeled as shown on architectural drawings or as built for existing building envelopes. **Exceptions:** The following building elements are permitted to differ from architectural drawings. (a) All uninsulated assemblies (e.g., projecting balconies, perimeter edges of intermediate floor stabs, concrete floor beams over parking garages) shall be separately modeled. Any other envelope assembly that covers less than 5% of the total area of that assembly type (e.g., exterior walls) need not be separately described provided that it is similar to an assembly being modeled. If not separately described, the area of an envelope assembly shall be added to the area of an assembly of that same type with the same orientation and thermal properties. (b) Exterior surfaces whose azimuth orientation and tilt differ by less than 45 degrees and are otherwise the same may be described as either a single surface or by using multipliers. (c) For exterior roofs, the roof surface may be modeled with a reflectance of 0.45 if the reflectance of the *proposed design* roof is greater than 0.70 and its emittance is greater than 0.75. Reflectance values shall be based on testing in accordance with ASTM E903, ASTM E1175, or ASTM E1918, and the emittance values shall be based on testing in accordance with ASTM C835, ASTM C1371, or ASTM E408. All other roof surfaces shall be modeled with a reflectance of 0.30. (d) Manual fenestration shading devices such as blinds or shades shall not be modeled. Automatically controlled fenestration shades or blinds may be modeled. Permanent shading devices such as fins, overhangs, and light shelves may be modeled.	Equivalent dimensions shall be assumed for each exterior envelope component type as in the *proposed design*; i.e., the total gross area of exterior walls shall be the same in the proposed and *baseline building designs*. The same shall be true for the areas of roofs, floors, and doors, and the exposed perimeters of concrete slabs on grade shall also be the same in the proposed and *baseline building designs*. The following additional requirements shall apply to the modeling of the *baseline building design*: **(a) Orientation.** The *baseline building performance* shall be generated by simulating the building with its actual orientation and again after rotating the entire building 90, 180, 270 degrees, then averaging the results. The building shall be modeled so that it does not shade itself. **(b) Opaque assemblies.** Opaque assemblies used for new buildings or *additions* shall conform with the following common, lightweight assembly types and shall match the appropriate assembly maximum U-factors in Table 5.5-2: • Roofs – Insulation entirely above deck • *Above-grade walls* – Steel-framed • Floors – Steel-joist • Opaque door types shall match the proposed design and conform to the U-factor requirements from the same tables. • Slab-on-grade floors shall match the F-factor for unheated slabs from the same tables. Opaque assemblies used for *alterations* shall conform with 5.1.3. **(c) Vertical Fenestration.** Vertical fenestration areas for new buildings and *additions* shall equal that in the *proposed design* or 40% of gross above-grade wall area, whichever is smaller, and shall be distributed uniformly in horizontal bands across the four orientations. Fenestration U-factors shall match the appropriate requirements in Table 5.5-2 for the applicable vertical glazing percentage for U_{fixed}. Fenestration solar heat gain coefficient (SHGC) shall match the appropriate requirements in Table 5.5-2 using the value for $SHGC_{all}$ for the applicable vertical glazing percentage. All vertical glazing shall be modeled as fixed and shall be assumed to be flush with the exterior wall, and no shading projections shall be modeled. Manual window shading devices such as blinds or shades shall not be modeled. The fenestration areas for envelope *alterations* shall reflect the limitations on area, U-factor, and SHGC as described in 5.1.3. **(d) Skylights and Glazed Smoke Vents.** Skylight area shall be equal to that in the proposed building design or 5% of the gross roof area that is part of the *building envelope*, whichever is smaller. If the skylight area of the proposed building design is greater than 5% of the gross roof area, baseline skylight area shall be decreased by an identical percentage in all roof components in which skylights are located to reach the 5% skylight-to-roof ratio. Skylight orientation and tilt shall be the same as in the proposed building design. Skylight U-factor and SHGC properties shall match the appropriate requirements in Table 5.5-2. **(e) Roof albedo.** All roof surfaces shall be modeled with a reflectivity of 0.30. **(f) Existing Buildings.** For existing *building envelopes*, the *baseline building design* shall reflect existing conditions prior to any revisions that are part of the scope of work being evaluated.

TABLE G3.1 (*continued*) Modeling Requirements for Calculating Proposed and Baseline Building Performance

No. Proposed Building Performance	Baseline Building Performance
6. Lighting Lighting power in the *proposed design* shall be determined as follows: (a) Where a complete lighting system exists, the actual lighting power shall be used in the model. (b) Where a lighting system has been designed, lighting power shall be determined in accordance with 9.1.3 and 9.1.4. (c) Where lighting neither exists nor is specified, lighting power shall be determined in accordance with the Building Area Method for the appropriate building type. (d) Lighting system power shall include all lighting system components shown or provided for on the plans (including lamps and ballasts and task and furniture-mounted fixtures). **Exception**: For multifamily living units, hotel/motel guest rooms, and other spaces in which lighting systems are connected via receptacles and are not shown or provided for on building plans, assume identical lighting power for the proposed and *baseline building designs* in the simulations, but exclude these loads when calculating the *baseline building performance* and *proposed building performance*. (e) Lighting power for parking garages and building facades shall be modeled. (f) Credit may be taken for the use of automatic controls for daylight utilization but only if their operation is either modeled directly in the building simulation or modeled in the building simulation through schedule adjustments determined by a separate daylighting analysis approved by the *rating authority*. (g) For automatic lighting controls in addition to those required for minimum code compliance under 9.2, credit may be taken for automatically controlled systems by reducing the connected lighting power by the applicable percentages listed in Table G3.2. Alternatively, credit may be taken for these devices by modifying the lighting schedules used for the *proposed design*, provided that credible technical documentation for the modifications are provided to the *rating authority*.	Lighting power in the *baseline building design* shall be determined using the same categorization procedure (building area or space function) and categories as the proposed design with lighting power set equal to the maximum allowed for the corresponding method and category in 9.2. No automatic lighting controls (e.g., programmable controls or automatic controls for daylight utilization) shall be modeled in the *baseline building design*, as the lighting schedules used are understood to reflect the mandatory control requirements in this code.
7. Thermal Blocks – HVAC Zones Designed Where HVAC zones are defined on HVAC design drawings, each HVAC zone shall be modeled as a separate *thermal block*. **Exception:** Different HVAC zones may be combined to create a single *thermal block* or identical *thermal blocks* to which multipliers are applied, provided that all of the following conditions are met: (a) The space use classification is the same throughout the *thermal block*. (b) All HVAC zones in the *thermal block* that are adjacent to glazed exterior walls face the same orientation or their orientations vary by less than 45 degrees. (c) All of the zones are served by the same HVAC system or by the same kind of HVAC system.	Same as Proposed Design.

TABLE G3.1 (Continued) Modeling Requirements for Calculating Proposed and Baseline Building Performance

No. Proposed Building Performance	Baseline Building Performance
8. Thermal Blocks – HVAC Zones Not Designed Where the HVAC zones and systems have not yet been designed, *thermal blocks* shall be defined based on similar internal load densities, occupancy, lighting, thermal and space temperature schedules, and in combination with the following guidelines: (a) Separate *thermal blocks* shall be assumed for interior and perimeter spaces. Interior spaces shall be those located greater than 15 ft from an exterior wall. Perimeter spaces shall be those located within 15 ft of an exterior wall. (b) Separate *thermal blocks* shall be assumed for spaces adjacent to glazed exterior walls; a separate zone shall be provided for each orientation, except that orientations that differ by less than 45 degrees may be considered to be the same orientation. Each zone shall include all floor area that is 15 ft or less from a glazed perimeter wall, except that floor area within 15 ft of glazed perimeter walls having more than one orientation shall be divided proportionately between zones. (c) Separate *thermal blocks* shall be assumed for spaces having floors that are in contact with the ground or exposed to ambient conditions from zones that do not share these features. (d) Separate *thermal blocks* shall be assumed for spaces having exterior ceiling or roof assemblies from zones that do not share these features.	Same as Proposed Design.
9. Thermal Blocks - Multifamily Residential Buildings Residential spaces shall be modeled using at least one *thermal block* per living unit, except that those units facing the same orientations may be combined into one *thermal block*. Corner units and units with roof or floor loads shall only be combined with units sharing these features.	Same as Proposed Design.
10. HVAC Systems The HVAC system type and all related performance parameters in the *proposed design*, such as equipment capacities and efficiencies, shall be determined as follows: (a) Where a complete HVAC system exists, the model shall reflect the actual system type using actual component capacities and efficiencies. (b) Where an HVAC system has been designed, the HVAC model shall be consistent with design documents. Mechanical equipment efficiencies shall be adjusted from actual design conditions to the standard rating conditions specified in 6.4.1 if required by the simulation model. (c) Where no heating system exists or no heating system has been specified, the heating system classification shall be assumed to be electric, and the system characteristics shall be identical to the system modeled in the *baseline building design*. (d) Where no cooling system exists or no cooling system has been specified, the cooling system shall be identical to the system modeled in the *baseline building design*.	The HVAC system(s) in the *baseline building design* shall be of the type and description specified in G3.1.1, shall meet the general HVAC system requirements specified in G3.1.2, and shall meet any system-specific requirements in G3.1.3 that are applicable to the baseline HVAC system type(s).

TABLE G3.1 (Continued) Modeling Requirements for Calculating Proposed and Baseline Building Performance

No.	Proposed Building Performance	Baseline Building Performance
11. Service Hot Water Systems		
	The service hot water system type and all related performance parameters, such as equipment capacities and efficiencies, in the *proposed design* shall be determined as follows: (a) Where a complete service hot water system exists, the *proposed design* shall reflect the actual system type using actual component capacities and efficiencies. (b) Where a service hot water system has been specified, the service hot water model shall be consistent with design documents. (c) Where no service hot water system exists or has been specified but the building will have service hot water loads, a service hot water system shall be modeled that matches the system in the *baseline building design* and serves the same hot water loads. (d) For buildings that will have no service hot water loads, no service hot water system shall be modeled.	The service hot water system in the *baseline building design* shall use the same energy source as the corresponding system in the *proposed design* and shall conform with the following conditions: (a) Where a complete service hot water system exists, the *baseline building design* shall reflect the actual system type using actual component capacities and efficiencies. (b) Where a new service hot water system has been specified, the equipment shall match the minimum *efficiency* requirements in Section 7.4.2. Where the energy source is electricity, the heating method shall be electrical resistance. (c) Where no service hot water system exists or has been specified but the building will have service hot water loads, a service water system(s) using electrical-resistance heat and matching minimum *efficiency* requirements of Section 7.4.2 shall be assumed and modeled identically in the *proposed* and *baseline building designs*. (d) For buildings that will have no service hot water loads, no service hot water heating shall be modeled. (e) Where a combined system has been specified to meet both space heating and service water heating loads, the baseline building system shall use separate systems meeting the minimum *efficiency* requirements applicable to each system individually. (f) For large, 24-hour-per-day facilities that meet the prescriptive criteria for use of condenser heat recovery systems described in Section 6.5.6.2, a system meeting the requirements of that section shall be included in the *baseline building design* regardless of the exceptions to 6.5.6.2. **Exception:** If a condenser heat recovery system meeting the requirements described in Section 6.5.6.2 cannot be modeled, the requirement for including such a system in the actual building shall be met as a prescriptive requirement in accordance with 6.5.6.2, and no heat-recovery system shall be included in the *proposed* or *baseline building designs*.
12. Receptacle and other Loads		
	Receptacle and process loads, such as those for office and other equipment, shall be estimated based on the building type or space type category and shall be assumed to be identical in the *proposed* and *baseline building designs*, except as specifically authorized by the *rating authority*. These loads shall be included in simulations of the building and shall be included when calculating the *baseline building performance* and *proposed building performance*.	Other systems, such as motors covered by Section 10, and miscellaneous loads shall be modeled as identical to those in the *proposed design*. Where there are specific *efficiency* requirements in Section 10, these systems or components shall be modeled as having the lowest *efficiency* allowed by those requirements.
13. Modeling Limitations to the Simulation Program		
	If the simulation program cannot model a component or system included in the *proposed design* explicitly, substitute a thermodynamically similar component model that can approximate the expected performance of the component that cannot be modeled explicitly.	Same as Proposed Design.

TABLE G3.1.1A Baseline HVAC System Types

Building Type	Fossil Fuel, Fossil/Electric Hybrid, & Purchased Heat	Electric and Other
Residential	System 1 – PTAC	System 2 - PTHP
Nonresidential & 3 Floors or Less & <75,000 ft^2	System 3 – PSZ-AC	System 4 – PSZ-HP
Nonresidential & 4 or 5 Floors & <75,000 ft^2 or 5 Floors or Less & 75,000 ft^2 to 150,000 ft^2	System 5 - Packaged VAV w/ Reheat	System 6 - Packaged VAV w/PFP Boxes
Nonresidential & More than 5 Floors or >150,000 ft^2	System 7 - VAV w/Reheat	System 8 - VAV w/PFP Boxes

Notes:

Residential building types include dormitory, hotel, motel, and multifamily. Residential space types include guest rooms, living quarters, private living space, and sleeping quarters.

Other building and space types are considered nonresidential.

Where no heating system is to be provided or no heating energy source is specified, use the "Electric and Other" heating source classification.

Where attributes make a building eligible for more than one *baseline* system type, use the predominant condition to determine the system type for the entire building.

TABLE G3.1.1B Baseline System Descriptions

System No.	System Type	Fan Control	Cooling Type	Heating Type
1. PTAC	Packaged terminal air conditioner	Constant Volume	Direct Expansion	Hot Water Fossil Fuel Boiler
2. PTHP	Packaged terminal heat pump	Constant Volume	Direct Expansion	Electric Heat Pump
3. PSZ-AC	Packaged rooftop air conditioner	Constant Volume	Direct Expansion	Fossil Fuel Furnace
4. PSZ-HP	Packaged rooftop heat pump	Constant Volume	Direct Expansion	Electric Heat Pump
5. Packaged VAV w/Reheat	Packaged rooftop variable air volume with reheat	VAV	Direct Expansion	Hot Water Fossil Fuel Boiler
6. Packaged VAV w/PFP Boxes	Packaged rooftop variable air volume with reheat	VAV	Direct Expansion	Electric Resistance
7. VAV w/Reheat	Packaged rooftop variable air volume with reheat	VAV	Chilled Water	Hot Water Fossil Fuel Boiler
8. VAV w/PFP Boxes	Variable air volume with reheat	VAV	Chilled Water	Electric Resistance

TABLE G3.1.2.6A Minimum Building Conditioned Floor Areas at Which Economizers Are Included for Baseline Systems 3 and 4

Climate Zone	Area Interior	Area Perimeter
1a,1b,2a,3a,4a	N.R.	N.R.
2b,5a,6a,7,8	15,000 ft^2	N.R.
3b,3c,4b,4c,5b,5c,6b	10,000 ft^2	25,000 ft^2

N.R. means that there is no conditioned building floor area for which economizers are included for the type of zone and climate. TABLE G3.1.2.6B

TABLE G3.1.2.6B Climate Conditions under which Economizers are Included for Baseline Systems 5 through 8 Climate Zone Conditions

Climate Zone	Conditions
1a,1b,2a,3a,4a	N.R.
Others	Economizer Included

N.R. means that there is no conditioned building floor area for which economizers are included for the type of zone and climate.

TABLE G3.1.2.6C Economizer High-Limit Shutoff

Climate Zone	High-Limit Shutoff
1b,2b,3b,3c,4b,4c,5b,5c,6b,7,8	75°F
5a,6a,7a	70°F
Others	65°F

TABLE G3.1.2.9 Baseline Fan Brake Horsepower

Supply Air Volume	Baseline Fan Motor Horsepower	
	Constant Volume Systems 1-4	Variable Volume Systems 5-8
<20,000 cfm	17.25 + (cfm - 20000) x 0.0008625	24 + (cfm - 20000) × 0.0012
≥20,000 cfm	17.25 + (cfm - 20000) x 0.000825	24 + (cfm - 20000) × 0.001125

G3.1.3 System-Specific *Baseline* HVAC System Requirements. *Baseline* HVAC systems shall conform with provisions in this section, where applicable, to the specified *baseline* system types as indicated in section headings.

G3.1.3.1 Heat Pumps (Systems 2 and 4). Electric air-source heat pumps shall be modeled with electric auxiliary heat. The systems shall be controlled with multi-stage space thermostats and an *outdoor air* thermostat wired to energize auxiliary heat only on the last thermostat stage and when outdoor air temperature is less than 40°F.

G3.1.3.2 Type and Number of Boilers (Systems 1, 5, and 7). The boiler plant shall use the same fuel as the *proposed design* and shall be natural draft, except as noted under G3.1.1.1. The *baseline building design* boiler plant shall be modeled as having a single boiler if the *baseline building design* plant serves a conditioned floor area of 15,000 ft^2 or less and as having two equally sized boilers for plants serving more than 15,000 ft^2. Boilers shall be staged as required by the load.

G3.1.3.3 Hot Water Supply Temperature (Systems 1, 5, and 7). Hot water design supply temperature shall be modeled as 180°F and design return temperature as 130°F.

G3.1.3.4 Hot Water Supply Temperature Reset (Systems 1, 5, and 7). Hot water supply temperature shall be reset based on outdoor dry-bulb temperature using the following schedule: 180°F at 20°F and below, 150°F at 50°F and above, and ramped linearly between 180°F and 150°F at temperatures between 20°F and 50°F.

G3.1.3.5 Hot Water Pumps (Systems 1, 5, and 7). The *baseline building design* hot water pump power shall be 19 W/gpm. The pumping system shall be modeled as primary-only with continuous variable flow. Hot water systems serving 120,000 ft^2 or more shall be modeled with variable-speed drives, and systems serving less than 120,000 ft^2 shall be modeled as riding the pump curve.

G3.1.3.6 Piping Losses (Systems 1, 5, 7, and 8). Piping losses shall not be modeled in either the proposed or *baseline building designs* for hot water, chilled water, or steam piping.

G3.1.3.7 Type and Number of Chillers (Systems 7 and 8). Electric chillers shall be used in the *baseline building design* regardless of the cooling energy source, e.g., direct-fired absorption, absorption from purchased steam, or purchased chilled water. The *baseline building design*'s chiller plant shall be modeled with chillers having the number and type as indicated in Table G3.1.3.7 as a function of building conditioned floor area.

TABLE G3.1.3.7 Type and Number of Chillers

Building-Conditioned Floor Area	Number and Type of Chiller(s)
≤120,000 ft^2	1 screw chiller
> 120,000 ft^2, < 240,000 ft^2	2 screw chillers sized equally
≥240,000 ft^2	2 centrifugal chillers minimum with chillers added so that no chiller is larger than 800 tons, all sized equally

G3.1.3.8 Chilled Water Design Supply Temperature (Systems 7 and 8). Chilled water design supply temperature shall be modeled at 44°F and return water temperature at 56°F.

G3.1.3.9 Chilled Water Supply Temperature Reset (Systems 7 and 8). Chilled water supply temperature shall be reset based on outdoor dry-bulb temperature using the following schedule: 44°F at 80°F and above, 54°F at 60°F and below, and ramped linearly between 44°F and 54°F at temperatures between 80°F and 60°F.

G3.1.3.10 Chilled Water Pumps (Systems 7 and 8). The *baseline building design* pump power shall be 22 W/gpm. Chilled water systems serving 120,000 ft^2 or more shall be modeled as primary/secondary systems with variable-speed drives on the secondary pumping loop. Chilled water pumps in systems serving less than 120,000 ft^2 shall be modeled as a primary/secondary systems with secondary pump riding the pump curve.

G3.1.3.11 Heat Rejection (Systems 7 and 8). The heat rejection device shall be an axial fan cooling tower with two- speed fans. Condenser water design supply temperature shall be 85°F or 10°F approach to design wet-bulb temperature, whichever is lower, with a design temperature rise of 10°F. The tower shall be controlled to maintain a 70°F leaving water temperature where weather permits, floating up to leaving water temperature at design conditions. The *baseline building design* condenser water pump power shall be 19 W/gpm. Each chiller shall be modeled with separate condenser water and chilled water pumps interlocked to operate with the associated chiller.

G3.1.3.12 Supply Air Temperature Reset (Systems 5 through 8). Supply air temperature shall be reset based on zone demand from the design temperature difference to a 10°F temperature difference under minimum load conditions. Design air flow rates shall be sized for the reset supply air temperature, i.e., a 10°F temperature difference.

G3.1.3.13VAV Fan Part-Load Performance (Systems 5 and 7). Minimum volume setpoints for VAV reheat boxes shall be 0.4 cfm/ft^2 of floor area served.

G3.1.3.14 Fan Power (Systems 6 and 8). Fans in parallel VAV fan-powered boxes shall be sized for 50% of the peak design flow rate and shall be modeled with 0.35 W/cfm fan power. Minimum volume setpoints for fan-powered boxes shall be equal to 30% of peak design flow rate or the rate required to meet the minimum outdoor air ventilation requirement, whichever is larger. The supply air temperature setpoint shall be constant at the design condition.

G3.1.3.15 VAV Fan Part-Load Performance (Systems 5 through 8). VAV system supply fans shall have variable-speed drives, and their part-load performance characteristics shall be modeled using either Method 1 or Method 2 specified in Table G3.1.3.15.

TABLE G3.1.3.15 Part-Load Performance for VAV Fan Systems

Method 1 – Part Load Fan Power Data	
Fan Part-Load Ratio	**Fraction of Full-Load Power**
0.00	0.00
0.10	0.03
0.20	0.07
0.30	0.13
0.40	0.21
0.50	0.30
0.60	0.41
0.70	0.54
0.80	0.68
0.90	0.83
1.00	1.00
Method 2 – Part-Load Fan Power Equation	
$P_{fan} = 0.0013 + 0.1470 \times PLR_{fan} + 0.9506 \times (PLR_{fan})^2 - 0.0998 \times (PLR_{fan})^3$ where P_{fan} = fraction of full-load fan power and PLR_{fan} = fan part-load ratio (current cfm/design cfm).	

TABLE G3.2 Power Adjustment Percentages for Automatic Lighting Controls

Automatic Control Devices(s)	**Non-24-hr and ≤5,000ft^2**	**All Other**
(1) Programmable timing control	10%	0%
(2) Occupancy sensor	15%	10%
(3) Occupancy sensor and programmable timing control	15%	10%

Note: The 5,000 ft^2 condition pertains to the total conditioned floor area of the building.